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OF MEN AND THE RIVER. STREAM POLLUTION AND ITS CONTROL IN THE KANSAS RIVER BASIN

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OF MEN AND THE RIVER

By Kenneth Sidney Davis

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Stream pollution and its control in the Kansas River Basin are described with respect to factors such as rainfall, prevailing wind velocities, temperature, and landscape. Discussions on water law are presented as well as the aspects of watersheds. The evolution of river planning includes flood control and navigation, irrigation, and public health. Pollution and a pattern for remedial action are discussed, including silt pollution.

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OF MEN AND THE RIVER

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Stream Pollution and Its Control in the Kansas River Basin

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Kenneth Sidney Davis

this man should be shot

FEDERAL SECURITY AGENCY

Public Health Service

1951

OF MEN AND THE RIVER

* * * *

Stream Pollution and Its Control in the Kansas River Basin

By

Kenneth Sidney Davis

Note to the Reader

* * *

This little booklet is something of a departure from the usual run of Federal government publications. Its author is not a regular government employee. He was hired by the U. S. Public Health Service, on a temporary basis, for this particular project, and in the performance of his assigned task his relation to the Service has been precisely analogous to the relation he might have with any commercial publisher, having signed a book contract.

He was asked to write about stream pollution in the Kansas River Basin. Factual material dealing with the subject was made available to him. For the rest, he was given a free hand--and for the result, including whatever errors of fact and interpretation may lie herein, he must bear the full responsibility.

--K. S. D.

Part One

THE FRAME OF THE PICTURE

1. To Begin With--

2. Of Sewage and Civilization

3. Suggestions from History

"I do not know much about gods; but I think that the river
Is a strong brown god--sullen, untamed and intractable,
Patient to some degree, at first recognized as a frontier
Useful, untrustworthy, as a conveyor of commerce;
Then only a problem confronting the builder of bridges.
The problem once solved, the brown god is almost forgotten
By the dwellers in cities--ever, however, implacable,
Keeping his seasons and rages, destroyer, reminder
Of what men choose to forget. Unhonoured, unpropitiated
By worshippers of the machine, but waiting, watching and waiting."

--T. S. Eliot, The Dry Salvages

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THE FRAME OF THE PICTURE

1.

To Begin With--

Our chief concern in this little book is with stream pollution in the Kansas River Basin. Stated thus baldly, the subject is likely to seem to you remarkably unattractive. It has to do with the offal of packing plants, the dung of man and beast, the wastes of manufacturing, the brine of oil fields, the debris of soil erosion. How could it fail to be unpleasant? Yes, and boring to boot....

No doubt you're willing to grant at the outset that the subject is an important one. It's important to you and me personally, touching us in many and various ways. For instance:

If you'd like to use your neighborhood waters for fishing and swimming or boating, water pollution has a good deal to do with your recreation. If you love the look of clean sweet streams and lakes in a green landscape, it has something to do with the aesthetic values of your life. It has some influence on your personal income, in so far as this is bound up with the economic and social welfare of your region. It may quite directly affect your occupation if you are a farmer or are employed in an industry which uses large quantities of water in its processes.

Most importantly of all, of course, it has to do with the health and well-being of you and your community. Unpleasant though the thought of it may be, the water you use in your household today is likely to be water that has been fouled and purified and then fouled again and purified again, over and over, before it reaches you: to be even more blunt about it, the water which goes down your gullet today may have gone last week through someone else's kidneys and intestines: and if it happens to reach you without adequate cleaning up, you're in trouble. Serious trouble.

You'll grant all this. Nevertheless, "pollution" is a particularly unlovely word, and you may fail to see how its connection with our inland waters can be expected to define a subject of general interest, though it fascinates sanitary engineers, public health officers, doctors of medicine, and the like. I think you'll change your mind, however, if you'll "dig into" this seemingly nauseous concern. You'll discover that boredom in this case, as in so many others, is but an aspect of ignorance. As knowledge increases, boredom flees. The subject assumes ever-deeper significances. The area of its implication widens to include matters of vital concern to all of us, and what seems at first fit for only the most pedestrian prose may come to seem a proper subject for flights of lyricism, if one chooses to make them....

You may recall that Victor Hugo did so choose when, in Les Miserables, he wrote his famous treatise on the sewers of Paris. He called it "The Interior of Leviathan," and in it he suggested that much of civilization's political economy, its system of values, its tendency toward death and dissolution, can be measured by the manner in which it handles its sewage. The Parisian manner, he cried, is a disastrous error. The refuse of the city which should manure the plain is, instead, "swept into the gulf." He went on, in typically exuberant hyperbole:

"Do you know what these piles or ordure are, collected at the corners of streets, those carts of mud carried off at night from the streets, the frightful barrels of the night-man, the fetid streams of subterranean mud which the pavement conceals from you? All this is a flowering field; it is green grass, it is mint and thyme and sage, it is game, it is cattle, it is the satisfied lowing of heavy kine at night, it is perfumed hay, it is golden wheat, it is bread on your table, it is warm blood in your veins, it is health, it is joy, it is life."

A sewer, he proclaims, is a mistake.

"'The drains of Rome,' says Liebig, 'absorbed the entire welfare of the Roman peasant.' When the Campagna of Rome was ruined by the Roman drains, Rome exhausted Italy, and when it had placed Italy in its cloaca, it poured into it Sicily, and then Sardinia, and then Africa. The drains of Rome swallowed up the world...." As for Paris: "Each eructation of our drains costs us one thousand francs, and this has two results, --the earth impoverished and the water poisoned; hunger issuing from the furrow and sickness from the river. It is notorious that at this very hour the Thames poisons London! and (in Paris) it has been found necessary to remove most of the mouths of the sewers down the river below the last bridge."

Now Victor Hugo, you'll remember, wrote thus of sewers in general because he was going to deal with the Paris sewer in particular. Jean Valjean, the hero of his tale, was to play an heroic role in the intestine of Leviathan. And perhaps this method of treatment, this procedure from the general to the particular, is best suited to our own subject. We are to deal in particular with stream pollution in the Kansas River Basin. Let us begin with rivers and stream pollution, and sewage disposal in general.

A great advantage derives from this method: it forces us to view our subject in a wide and long perspective. We may thus avoid an error which we Americans are prone to make--namely, the mistaking of means for ends. After all, we are primarily a nation of technical specialists; our great genius lies in technical administration, in large-scale engineering, in big business organization; and in consequence we are inclined to take partial, specialized, mechanical views of what can be accurately seen only as living organic wholes. As engineers, we are likely to become so wound up in vast construction projects that we forget (if we ever knew) the purposes those projects are to serve. For it is in the whole, and never in its parts, that ultimate purpose and value is to be found. The true meaning of our work is derived from general considerations, never from particular operations, which is to say that unless we see and have some understanding of the whole we can never really know what we are doing.

Let us try, therefore, to see stream pollution control as but one element in a complex of water use developments, and the Kansas River Basin as but one element in a much larger river basin--and to see the whole in terms of history. River development is a long-time concern. It requires, for its accurate perception, an historic view.

2.

Of Sewage and Civilization

Victor Hugo's interest in sewage disposal, his sense of its importance to history, has not, alas, been shared by many historians. An unfortunate fastidiousness, joined perhaps by lack of industry and a failure of imagination, seems to have operated as censor, denying to written history all but the meagerest references to the matters which here concern us.

Indeed, you may have noticed and deplored, a general tendency of historians to ignore much of truly vital import in history, while giving vastly disproportionate accounts of Big Shots and of the Great Events in which Big Shots play their self-inportant roles. The froth is mistaken for the wave of history. What of soil depletion and erosion as a factor in the decline and fall of the Roman Empire? Gibbon, in his monumental work, scarcely mentions it. What of malaria as a weakener of Italian vitality in the centuries following Augustus? Again there is almost complete silence. Who knows the names of Rome's greatest architects, her hydraulic engineers, her civil engineers, men whose discoveries permanently enriched our skills and whose constructions still stand throughout the Mediterranean world as evidence of their genius? We hear of Sextus Julius Frontinus, the engineer who headed Rome's water department in 100 A. D. We hear of him but faintly, and only because he himself wrote books still extant. We hear of others not at all.

Thus our sketchy researches into the ancient and medieval history of sewage disposal may not have given us as much information as we'd like. They have, however, indicated that the problem began when men first crowded into cities and that the manner of its solution can tell us a great deal about the standards of living, and the rights of ordinary people, in earlier civilizations.

The relative importance of property rights and individual human values can be so measured. It may be stated as maxim that sanitary sewage disposal varies in direct proportion, not with technical competence (which is sometimes much higher than prevailing sewage disposal methods would indicate), but with the social importance of ordinary citizens. Only as ordinary men become influential, either by direct participation in policy-making or by mass pressures on policy-makers--only then do we find large-scale water and sewer developments. Rigidly stratified societies are virtually certain to avoid such expenditures unless and until the ruling elite recognizes that its own physical health, its creature comforts, and its social privileges are threatened by lack of them.

In medieval England, for instance, sanitary policy seems not to have begun until a king was personally offended by the filthy habits of his subjects. In a Royal Order to the Mayor and Sheriffs of London, issued in 1357, Edward III tells how, as he rode along the Thames, he "beheld dung and lay-stalls and other filth accumulated in divers places in the said City upon the bank of the said river" and "also perceived the fumes and other abominable stenches arising therefrom: from the corruption of which, if tolerated, great peril, as well to the persons dwelling within the said City as to the nobles and others passing along the river, will it is feared arise unless indeed some fitting remedy be speedily provided for the same." The City government thereupon prescribed that "for saving the body of the river, and preserving the quays... for lading and unlading, as also for avoiding the filthiness that is increasing in the river and upon the banks of the Thames, to the great abomination and damage of the people," rubbish and filth were not henceforth to be thrown into the Thames or "Flete" but must be taken out of the city by carts. But Simon, in his authoritative book, English Sanitary Institutions, indicates that Edward's will was by no means fully executed, for in 1372 another Royal Order complains "that 'rushes, dung, refuse, and other filth and harmful things... from City and suburbs are thrown into the water of Thames, so that the water aforesaid and the hythes thereof are so greatly obstructed, and the course of the said water so greatly narrowed, that great ships are not able, as of old they were wont, any longer to come up to the same City, but are impeded therein: and the writ enjoins immediate measures to amend this state of things, and to prevent recurrence.'"

Medieval England was of course a crudely primitive land when measured against earlier civilizations. Undoubtedly the Londinium of the Romans, with 60,000 souls and paved and sewered streets, was much more sanitary than the London of Edward III. But in many of these earlier civilizations, sanitary engineering, though technically quite highly developed, seems to have been confined, for the most part, to the palaces of kings, priests, and noblemen.

On the Island of Crete, for example, there had developed by 2,000 B. C. a civilization not only rich in artistic talent but skillful in the sanitary disposal of its rubbish--a combination of talent and skill which is by no means inevitable. (The greatest artists often know little of plumbing, and there are people of doubtful wisdom who talk as though America's skill in the latter were actually hostile to art.) The largest city of Crete was Knossos. It is famed in Greek mythology as the capital of King Minos whose palace, the Labyrinth, was guarded by the frightful Minotaur. Actually all Cretan rulers seem to have been called Minos, just as all Egyptian rulers were called Pharoah, and archaeologists have found the Labyrinth to be "a building as stately, complex, and luxurious as any in the ancient world." The quotation is from H. G. Wells, who goes on to say that we find here "waterpipes, bathrooms, and the like conveniences, such as have hitherto been regarded as the latest refinements of modern life." We find, too, a notable sanitation system. Huge circular stone-walled pits, called kouloura and arranged in line, were constructed for the sanitary disposal of rubbish. Earth was apparently used in layers to prevent noxious odors, and surface water was drained into them to aid the digestion of sewage. This skill, however, was confined to the palace area. There seems no evidence that it was widely applied to the welfare of the masses.

In the Indus Valley of Northwest India, on the other hand, the evidence is clear. This remarkable civilization, whose remains have been but lately discovered, flourished in 3,000 B. C. and it was even then millenia old, for it was of vast extent and advanced organization. Unlike the early civilizations of Mesopotamia and Egypt, that of the Indus Valley was predominantly secular: religion, though present, did not have ruling power: and there is perhaps a causal connection between this fact and the fact that Mahenjo-daro, the chief city thus far excavated, had splendid sewers. Priest-ridden societies are despotic in form and other-worldly in outlook. Their engineering talents are (as we've indicated) generally devoted to the dwellings of rulers, the monuments by which rulers glorify themselves, and the temples whose worship is a pacifier of miserable men. But at Mahenjodaro the most elaborate structures were designed for the use of citizens (one public bath covered a large block), and the water and sewer systems compared not unfavorably with those of American cities today. Many of the houses were of two stories, and had bathrooms. Their drains were connected into covered sewers which ran along the streets, feeding into trunk lines which, in turn, fed into the river. Every street, every alleyway, every passage had its own covered conduits of finely-shaped and precisely-laid brick.

As for ancient Rome, she began her career as a republic, and her later empire had a wider diffusion of governing power and a closer concern for the popular will than any preceding Great State had had. It seems fitting, therefore, that among the first of her massive engineering enterprises was the Cloaca Maxima.

The stone arches of this mighty sewer were so wide and tall that a wagon loaded with hay could pass under them. Into it fed a large and increasingly complex sewer system draining off not only the city's refuse and storm water but also the marshes which divided the Seven Hills and upon whose dried beds, as the city grew, were raised tenements, and palaces, and great public buildings. The Cloaca Maxima opened into the Tiber, which also served as a main source of city water until Appius Claudius the Blind built the first aqueduct in 312 B. C. Subsequently thirteen other aqueducts were built, the average length being slightly less than 100 miles, and they carried 300,000,000 gallons of fresh water daily from the mountains to giant city reservoirs. From these latter was piped water for household use, for magnificent public baths, for tremendous mock sea battles in the arenas--and for sewage disposal.

The Roman cities were perhaps more sanitary, in general, than any of their predecessors had been. Certainly their engineering devices for insuring a clean fresh water supply, and for flushing out their waste products, were considerably in advance of those in earlier great towns--with the possible exception of the ancient Indus cities about which so little is known. As masters of hydraulics the Romans were tremendous. But they neglected certain other matters of vital concern, and one portent of their ultimate doom was the darkly-flowing Tiber, thick with eroded soil from the uplands. The river's pollution plagued Rome, and literally, through all the long ages of her greatness. It was partly in consequence that there developed, in the late years of the Empire, the beginnings at least of a system of public health officers: Gibbon tells how Valentinian, about 370 A. D., established "fourteen skillful physicians, with stipends and privileges, in the fourteen quarters of Rome."

For Rome, at the height of her glory, remained by modern American standards sick and filthy-- and sick because filthy. She was so sick in an average year that a modern American would have hesitated to visit her. Typhoid fever and dysentery were in continuous epidemic, tuberculosis carried off whole families, malaria enervated the body politic through three centuries before the German barbarians destroyed it completely; and all these are diseases whose transmission is associated with polluted waters....

Nor is it irrelevant to point out that Rome inherited from the preceding Great Powers in her theater of operations a "disease" of soil impoverishment and erosion which, under Roman organization, became progressively more serious. Such a disease accelerates as it proceeds. In the later years of the Empire, it became a kind of "galloping consumption" which transformed fertile plains into sandy deserts, shredded fat slopes into raw gullies, and ripped the soil off denuded mountains at the greatest rate, perhaps, that it ever achieved until we Americans set out to ruin a continent. Victor Hugo should have meant soil erosion as well as soil exhaustion when he spoke of Italy, and Sicily, and Sardinia, and North

Africa as pouring down the insatiable Roman gullet. And to the lands he mentioned should have been added Spain, Greece, Palestine, Phoenicia, the whole of the Middle East.

The author of this booklet has himself seen the vast yellow deserts of Syria, where rich soil once nourished immense populations. It was counted the most stable and prosperous of Roman provinces; twelve millions lived in plenty where three now live in poverty. He has walked the streets of Palmyra, once the rich and powerful center of a flourishing culture and now an immense, solitary ruin in a waste of naked pebbles. He has stood above Tyre and Sidon on the Lebanon where great cedars grew for Solomon's temple and for the palaces of Pharoahs--bare now, and reduced to subsoil and naked rock. Erosion by wind and water wrought these sad changes. And such bitter sights must convince the most skeptical that man's violation of nature's economy is a grievous sin whose wages are, indeed, death. And desolation.

Now the relevance of soil exhaustion to public health in the ancient Mediterranean world did not consist alone of its effects on food supply, which was of course reduced in quantity and nutritional value. It consisted also of the effects upon streams and rivers which, clogged with erosion debris, became so turbid that they could no longer cleanse themselves, in a few flowing miles, of the organic wastes dumped into them. The Tiber, which could easily have digested the sewage of early Rome, may well have become a stinking, disease-breeding mass of liquid mud below Rome in the later days of the Empire (we know that the river had to be repeatedly dredged in order to maintain its channel)--and similar catastrophes must have befallen other streams flowing past mighty cities. Moreover, downstream lakes and reservoirs, filling with silt, must often have been transformed into swampy breeding grounds for malarial mosquitoes. This may partially account for the fact that malaria, which turns virile men into listless weaklings in ever-recurring spasms, was apparently not widespread in Italy until some years after the birth of Christ....

3.

Suggestions From History

Let us now sum up our four sketches from history and see what lessons are in them for us. We've presented them, as you've observed, in a certain order: an order of the increasing social importance of ordinary citizens, as this is measured by sewage disposal systems. You may also have observed that this order coincides with another: in each of our examples the sewage and pollution problem has a wider area of reference than it had in its predecessor.

In medieval London the problem presented itself as an annoyance and possible health-threat to the nobility, and the attempt to solve it, focussed exclusively on the Thames, consisted simply of ordering common folk to relocate their latrines, to cease dumping into the river, and to cart their refuse instead from the city.

In ancient Crete we found a much greater technical skill displayed in the construction of water and sanitation systems, with effective septic tanks to digest refuse from the palace area. There was no clear evidence, however, that this skill served great masses of people.

In the Indus civilization, on the other hand, ordinary citizens *were* served by large, complex water and sewer systems, with covered conduits draining houses, feeding into lines along the streets, and thence into trunk lines opening upon the river.

And in Rome also this is true. But our more extensive knowledge of Rome enables us to see her sewage and pollution problem as part of a much larger problem of water economy. The use of rivers for sewage disposal was complicated by erosion of the uplands, which also had unhappy effects upon navigation, water supply, and (undoubtedly) the use of inland waters for recreation.

Clearly, it is from the Roman experience that we Americans have most to learn. It teaches us that stream pollution, and the use of streams for sewage disposal, is by no means a problem of the stream alone, nor is it exclusively a problem of the stream and its immediately contiguous land. It is also a problem of the uplands and their uses. The stream is but part of a landscape. It is an organic element of a watershed whose various problems are all interrelated, being but aspects of one total problem, and this means that the stream cannot on a large scale nor in the long run be treated successfully as an isolated thing. At the beginning of large-scale plans, the whole watershed must be considered as organism. Otherwise the plans may fail in the end.

The Romans themselves never really learned this lesson. They resembled us Americans in that they were the great administrators, organizers, and engineers of their age--and the greatest exploiters of natural resources. Slowly, partially, and too late, the more astute among them came to realize that some of the roots of their urban civilization were withering for lack of natural sustenance. We find Cyprian, in the Third Century A. D., bemoaning the fact that "the world has grown old and does not remain in its former vigor;" that "the rainfall... is diminishing" and "the metals are nearly exhausted;" and that "the husbandman is failing in the fields." We find increasingly numerous references, in the years of decline, to deforestation, soil exhaustion, and clogged irrigation ditches in deserts which once richly bloomed. But we do not find this consciousness organized into the practical forms needed for a reversal of the anti-vital trend.

The clue to what the Romans should have done, as well as to their failure to do it, may perhaps be found in a famous statement by Cicero. This greatest lawyer of a race of master lawyers was himself a countryman, born and reared in a villa in the foothills of the Apennines, and he was convinced of the necessity for agreement between men's legislation and the natural order of the universe. But, as a Stoic philosopher, he went farther than this; he identified the natural order with man's moral code, assuming the latter (in so far as it was valid) to be the product of an inborn "natural reason." He summed up his basic view as follows:

"True law is right reason in agreement with nature, world-wide in scope, unchanging, everlasting.... We may not oppose or alter that law, we cannot abolish it, we cannot be freed from its obligations by any legislature, and we need not look outside ourselves for an expounder of it. This law does not differ for Rome and for Athens, for the present and for the future; ...it is and it will be valid for all nations and all times.... He who disobeys it denies himself and his own nature."

This has the merit of recognizing that there are laws of nature whose contravention by man's legislation always leads, through more or less disaster, to defeat of the latter. We may well applaud the assertion that "right reason in agreement with nature" lies at the root of all just man-made law, and we may regret the Roman failure (and our own) to apply to problems of land and water use this principle of harmony. But we can also understand the failure when we note that, in Cicero's view, the "law of nature" can be discovered simply by introspection, and that he seems to posit an inflexibility of legal structure which is distinctly unnatural in that it ignores all elements which are fluid and changing, including the creative elements of human nature. The discovery of nature's laws requires more intellectual humility than Cicero seems to have realised. It requires that we look outside ourselves and subordinate to objective sense-data not only our egoistic wills but also those "self-evident truths" which have so often led philosophers astray....

But we ourselves must not stray into by-paths, however attractive. Suffice it here to say that we shall return to this all-important theme of natural harmony and that we shall find, in the vast structure of Roman law, a solid connecting link between this mightiest of ancient peoples and our particular problem of stream pollution in the Kansas River Basin.

Part Two

PORTRAIT OF A WATERSHED

1. The Watershed as Landscape
2. The Watershed as Process
3. Two Sources of Water Law
4. An Emerging Concept: the Watershed as Organism

PORTRAIT OF A WATERSHED

1.

The Watershed as Landscape

We speak of the "basin" of the Kansas River, and the word is not inaccurate as description. The basin, however, is of peculiar shape. Were the sky which covers it a solid substance whose horizons coincided with the highest ridges of watershed, the basin would be transformed into a vast pinch bottle some 500 miles long and (viewed from above) 190 miles wide at its widest portions, gently sloping from west to east and tapering abruptly at its eastern end to form a narrow bottleneck. This neck would have as its eastern terminus a relatively tiny opening, only a few hundred yards wide--the width of the Kansas River itself as it flows into the Missouri.

The basin as a whole contains approximately 60,060 square miles. It also contains both the geodetic and geographic centers of the United States: the former, from which longitude and latitude are calculated, is in Osborne County, Kansas, and the latter is on the Fort Riley, Kansas, Military Reservation some 100 miles to the east. Roughly 16 percent of the total area lies in Colorado, 28 percent lies in Nebraska, and the remaining 56 percent is in Kansas. Actually the main stem of the Kaw (the name by which the river is known to all who live in its valley) flows only 169 tortuous miles, or about 135 in a straight east-and-west line, from Junction City, Kansas, to Kansas City. It drains but 5,554 square miles, barely nine percent of the total basin area. Its main tributary, the Blue, flowing down from the north through a particularly lovely valley and meeting the Kaw at Manhattan, 120 miles above Kansas City, drains a much larger area--some 9,600 square miles in east central Nebraska and Kansas.

Larger still are the sub-basins of the Republican and Smoky Hill Rivers which flow together at Junction City (so named for that reason) to form the Kaw. The Republican's drainage area contains nearly 25,000 square miles, the bulk of it in western Nebraska, western Kansas, and eastern Colorado. The Smoky Hill, with its two main tributaries, the Solomon and the Saline, drains approximately 20,000 square miles. A tiny portion of this area lies in eastern Colorado. The rest lies in central and western Kansas.

Thus, the general composition of the Kansas River Basin. No spectacular ridges, no grandeurs of mountain peak, separate it from the North Platte and Nemaha basin to the north and northwest, nor from the Arkansas and Marias des Cygne basin in the south and southwest. Only by careful survey have civil engineers determined the precise edge of the bowl, the ultimate contour line dividing rain between this basin and its immediate neighbors. Nevertheless one climbs a mountain height as one travels from the eastern to the western limits. The elevation at Kansas City is some 770 feet; the elevation in Lincoln County, Colorado, where the basin has its farthest western tip, is around 4,300 feet; and the difference of more than 3,500 feet is about equal to the climb from base to top of a typical

14,000-foot peak in the Colorado Rockies.

One also, travelling from east to west, moves in steady and swift progression from a land of sufficient rain through a land of uncertain rain into a land where rain, in an average year, is a rare event and ground water a precious commodity. At Kansas City, the average annual precipitation is between 35 and 40 inches a year. At Junction City, 145 miles to the west, it averages 30 inches a year. At the 99th meridian, halfway across the basin, it averages 25 inches. One hundred miles beyond that, it averages only 20 inches; and in the far western reaches of the basin the country approaches desert conditions, the rainfall averaging but little more than 15 inches--which means a good deal less than that falls in many years. Indeed, this deficiency of rain in the west would render inaccurate an assertion that the Republican River actually *drains* 25,000 square miles. That area is, as we've said, encompassed in the watershed, but some thousands of these miles are marked on drainage maps as "noncontributing areas;" no significant amount of runoff water flows from them into the central streams.

To those concerned with stream pollution, soil conservation, and flood control, the manner in which the rain comes to this land is as important as the amount which comes. Other areas, having no more moisture than Kansas and Nebraska in an average year, may escape the droughts which plague this region--and the frequent floods which greatly augment stream pollution. They may do so because their rains are more evenly distributed through the seasons, are more frequent and less furious. In the Kansas Basin, and particularly in the middle and western portions, much of the rain which falls does so as a liquid lash across the land. Huge drops strike all naked earth so violently as to shatter its surface into dust-sized particles. These, caught up and held in suspension, quickly clog the earth pores and prevent the absorption which would otherwise occur. "Puddling," this is called. Its consequence is a high proportion of runoff, swelling the streams with moisture, and increasing their turbidity with soil, badly needed on the uplands.

Differences in prevailing wind velocities between the eastern and western portions are almost as great as the differences in rainfall. In the eastern portion, winds are not perceptibly higher than they are in eastern United States as a whole, but the western portion is among the windiest of all inland sections of the continent. A stranger to the High Plains is always impressed and often dismayed by the seemingly endless storm of wind he encounters there. He has to lean against it as he walks, and squint his eyes against its blast. He hears it sobbing around the corners of houses and moaning through the scant-leaved boughs of rare and stunted trees. In winter, he sees it defined in clouds of dust or snow across the fields. Dust storms are common in those seasons when the cultivated earth is bare of vegetation, and their severity in years of extreme drought is both spectacular and terrifying.

The normal annual mean temperature throughout the basin approximates 50 degrees F., with a winter mean of around 25 degrees and a summer one of around 75 degrees. This tells one little, however, of actual temperatures as residents experience them, for the basin lies in the path of air currents flowing north from the Tropics and south from the Arctic, and the temperatures in any given locality have wide and (sometimes) swift variations. In an average year, the range between summer and winter temperatures is around 100 degrees, but in any one year it may be much greater. In Manhattan, Kansas, for instance, the temperature range in a recent year was some 140 degrees--from around 32 degrees below zero to nearly 110 degrees above--and for the basin as a whole (though not in the same year) the range has been 165 degrees: from 47 below zero to 118 above. In general, the western tablelands are somewhat cooler than the lower lands to the east. A summer evening on the High Plains is normally pleasant, even when the preceding afternoon is blazing hot, and visitors from more humid areas are likely to speak gratefully of sleeping under blankets at night despite a temperature reading at 3 P. M. of 100 degrees.

It should be added that the wide difference between temperature extremes does not deny to the region its fair quota, if not more, of pleasant healthful weather. The long springs and autumns are lovely seasons, and there have been years in Kansas (1950 is one of them) in which the countryside remains as lushly green all summer long as rural New England, and the thermometer seldom registers more than 85 degrees. Few if any areas of equivalent rainfall have a higher percentage of cloud-free days: the relative humidity on the average is low, and fogs or mists are very rare. This means, of course, a high evaporation rate--a factor of importance to the natural water economy, and hence to river development plans, across the plains....

In terms of climate, then, the basin may be roughly divided into three areas, each occupying a third of the distance from the mouth of the Kaw to those remote western highlands where the Arikaree, famed in Indian wars, has its sources. And these climatic conditions coincide, though again very roughly, with three quite different kinds of landscape--differing in shape, in color, in natural vegetation.

The eastern landscape is one of stream and river flood plains, flat and rich and varying in width from a mile or so to 15 or 20, bounded by limestone hills rising 200 to 500 feet above the valley floors. Here corn is a principal crop, and a widely-diversified farming is practiced; here, too, are found the largest towns of the region. Trees grow tall and thick along the rivers and in farm woodlots: village streets lie in the deep shade of high-arched dense-leaved branches. The rock-ridged hills themselves--shaggy with tall grasses where ungrazed, bearing few trees on their sides and none on their crests--become the dominant feature of the Kansas landscape a few miles west of Topeka. These are the Flint Hills, components of the Bluestem Belt, whose vistas of surpassing liveliness invariably surprise strangers accustomed, as most of them are, to thinking of this whole region as a flat monotonous plain. The hills form a belt some 30 to 40 miles wide, extending south from beyond the Nebraska line into Oklahoma, and to them are shipped for summer grazing a third of a million cattle each year, most of them from the American southwest but some of them from Mexico. It is a unique grazing area. The bluestems and their associated grasses are so lush in their growth, and so nourishing, that many cattle are actually finished on them, selling grass-fat and profitably on the Kansas City and Omaha markets. The prevailing color-note through the whole of this landscape, in summer, is a deep blue-green.

This bleaches toward a yellow-green as one moves into the middle landscape, beyond the bluestem belt. This portion of the basin bulges 83 miles into Nebraska and 106 miles into Kansas and its scenery is less impressive than the Flint Hills. The valleys are wider, the hills lower, and of natural vegetation the bluestems, which mingle on equal terms with short grasses on the lower reaches of the Republican and Smoky Hill, give way to earth-hugging buffalo grass as one travels westward, steadily climbing. Also, corn gives way to wheat as a principal crop, though corn is grown farther west in Nebraska than it is in Kansas. Drouth-resistent sorghums, especially developed for this region by state agricultural experiment stations, assume more important roles in the farm economy, and there is somewhat less diversity of crops. Trees become fewer and smaller, the woods on river banks consist at last chiefly of stunted cottonwood thickets, and the rivers themselves are generally wide and shallow: they carry less water, of course, as one moves toward their sources. On every hand the horizons widen out, farther and farther, toward the immense solitudes of the High Plains.

These, the High Plains, constitute the western landscape of the basin. On first acquaintance they appear to be a vast flat monotony, a waveless sea of earth circled by a distant rim of sky: the prevailing color is brown, or gold, or faded yellow-green, depending on the season and the rainfall. The plains seem utterly featureless. One is aware at first only of vast empty spaces, and feels the terror or the gratefulness of them: the Big Shot (symbol and type of our age's madness) may sense with a shudder his own insignificance under such terrific skies, while a man satisfied to be simply and honorably a man is soothed by the reminder that Big Shots, with their sick love of Power and their ruthless egotisms, are not after all the sole arbiters of the universe. But as one comes to know these plains better, one perceives that they are not featureless. One perceives austere beauties composed, with classic restraint, of the simplest elements: a towering cloud mass hued with evening in the west, a subtle variation in the pattern of wheat and short milos and buffalo grass, a lonely farmhouse standing strangely proud and sombre at the edge of a shallow ravine.

Here trees, by their rarity, become centers of the watcher's attention; instead of merely ornamenting a view, they become the ordering principles of it. For this is all short-grass country of little rain, a magnificent range for buffalo and antelope and elk in those wilderness years when it was mapped as the "Great American Desert," a magnificent range for cattle when the railroads first opened it to eastern markets. Great stretches of range, fenced now, yet remain--but this is predominantly a land of wheat, and there are few sights more impressive or more lovely in its own way than the golden fields just before harvest, flowing in endless waves before the wind. Afterward the fields are plowed and cheerless, helpless against whatever heavy rain may come or against the ceaseless wind if rain comes not at all. The rivers in this country are all shallow and mostly of intermittent flow; their sandy beds often swallow completely the water assigned to them by the surrounding fields....

2.

The Watershed as Process

The watershed, however, is not only landscape; it is also a natural process, and there is evident in nature a tendency of all processes to "strike a balance" and of all variations of phenomena to "smooth themselves out."

The water in two jars, sitting side by side on a table and connected by a tube, will seek the same level, water flowing from the more to the less full until a balance is struck: this is the essential process of a siphon, or of a waterworks operated by gravity. Two salt solutions of different densities, separated by a permeable membrane, will tend to equalize their concentrations, solvent flowing from the less to the more dense until the difference is erased: this is the essential process of osmosis. Bodies of different temperatures, lying side by side, will tend toward the same temperature, the warmer body losing heat and the cooler one gaining it until equality is achieved: this is the essential process described by the second law of thermodynamics.

This general tendency of nature toward a silent, motionless monotony is well and widely known. It has been used to sustain all manner of pessimistic philosophies. The universe is running down, some say, and all things sink or rise toward the same dead level. The sun is a cooling star, they say, and all vital tensions are being slowly but inexorably relaxed as energizing differences are, one by one, removed. Such pessimism gains plausibility from the fact that its corrective, in nature, is little known and far less perfectly understood. What force raises mountains, and thus counteracts the levelling process of land erosion? Who can explain the rise of truly great men, whose creative effort prevents utter social stagnation? Are there not factors which interrupt and revitalize what must otherwise be a dull physical chain of action-reaction, proceeding steadily, predictably, fatally?

In any case, when we look upon our Kansas Basin as a natural process, or a compendium of natural processes, we might expect to find it seeking a balance of the forces within it. We'd expect to detect a levelling procedure, whereby that which is high is lowered and that which is low is raised: we'd expect water, seeking its own level and operating on erosible materials, to wear away the uplands and build up, with erosion debris, the lowlands; and we'd expect the rivers to flow ever-more-sluggishly as the process continued, tending toward an ultimate stagnant pool spread thinly over a land surface utterly flat. We'd expect to find vegetable and animal life tending toward stability, seeking and perhaps achieving a balance in which the death of one fed the life of another, and the waste products of one were the vital sustenance of another--while all proceeded slowly together, and inevitably, toward ultimate extinction. The unhappy end would be so far distant, however, as to be imperceptible and we could anticipate its prevention, at some future time, by a new creative cataclysm.... All this we'd expect to find--and all this we do find.

It is a mistake to assume, as some conservation enthusiasts have done, that stream pollution, and floods, and soil erosion are wholly unnatural phenomena produced by the white man's enterprise. The very first glimpse which history gives us of the Missouri shows it in angry flood, thick with mud and clogged with debris. Francis Parkman tells in his LA SALLE AND THE DISCOVERY OF THE GREAT WEST how Marquette and Joliet paddled in their birch bark canoes down the Mississippi in June of 1673, and how they saw, some miles below the mouth of the Illinois and to their left, a huge rock cliff on which were painted a pair of monsters, all red and black and green. These manitous or Indian gods frightened Marquette, as he frankly states in his journal. He and his companions talked of them for a long time as they continued downstream.

"They were thus engaged," writes Parkman, "when they were suddenly aroused by a real danger. A torrent of yellow mud rushed furiously athwart the calm blue current of the Mississippi; boiling and surging, and sweeping in its course logs, branches, and uprooted trees. They had reached the mouth of the Missouri, where that savage river, descending from its mad career through a vast unknown of barbarism, poured its turbid bloods into the bosom of its gentler sister. Their light canoes whirled on the miry vortex like dry leaves on an angry brook. 'I never,' writes Marquette, 'saw anything more terrific....'"

Father Membre's account of La Salle's expedition, in 1681 and 1682, confirms this first impression of the Missouri as a turbid river, dark-yellow with eroded soil. Writes he:

"Then (on January 13, 1682) we set out (from the mouth of the Illinois), and, six leagues lower down, found the Osage (Missouri) river coming from the west. It is full as large as the river Colbert (Mississippi), into which it empties, troubling it so much that from the mouth of the Osage the water is hardly drinkable.... (It) pours in so much mud that, from its mouth, the water of the great river, whose bed is also slimy, is more like clear mud than river water."

Be it remembered that one element of the "vast unknown of barbarism" through which the Missouri descended in its "mad career" was the Kansas River Basin. And some of the "clear mud" which Father Membre describes was poured into the Missouri through the mouth of the Kaw. Col. John C. Fremont, whose expedition went up the Kaw Valley in 1842, twelve years before the white man began his settlements here, tells in his report of reaching a ford in the late afternoon of June 14th, only to find that "it (the river) had been swollen by the late rains, and was sweeping by with an angry current, yellow and turbid as the Missouri." The highest flood ever recorded on the Lower Missouri occurred in 1844, when a high crest coming down the Kaw coincided with one coming down the upper reaches of the Big Muddy.

But though stream pollution, and floods, and soil erosion are thus shown to be integral to the watershed as natural process, there can be small doubt that the white man's enterprise and carelessness have increased the former two while accelerating the latter. This is attested to by the accounts of other early travellers and by many portions of Fremont's own report. These contain references to "crystal clear" streams abounding in fish, streams that now are thick with mud and afford small sport to fishermen. Fremont writes of making bivouac on "some well-timbered ravines near the Little Blue," and of "crossing the next morning a number of handsome streams with clear water and sandy beds." One would not find those streams so handsome today, nor be able to see, through their veils of dark water, whether their beds were rock or sand or black oozy earth. The very name of the Blue indicates a great change in its appearance during the last century, a change which measures a vast increase in its pollution. The river was so named because, when first seen by white men, it was blue; it reflected like crystal and azure heavens. Now its prevailing color is a dirty yellow-brown.

Moreover, the early history of the Kansas-Nebraska territory reveals main rivers to have been navigable far above their mouths, rivers that now are strewn with shoals of sand and too shallow, when not in flood, or near it, to bear craft drawing much deeper than a row boat. Edward Everett Hale, in his remarkably accurate KANSAS AND NEBRASKA (a book published in 1854 to help the work of the Emigrant Aid Companies), writes of the "Kanzas river" as navigable from its mouth all the way to the Republican Fork, save in seasons of drouth. The Republican, too, "is navigable farther up" beyond its lowest reaches though "no explorations have been made public to show how far." He points out that "a steamboat carried up the supplies needed for the building of Fort Riley, the new government post at the mouth of the Republican Fork."

In those years the levelling tendency of water and wind erosion was inhibited by a precarious balance of life forces in the watershed, a balance developed through long ages of vital struggle. Woods covered hillsides in the eastern portion of the basin, and the leaf mulch which formed beneath them soaked up rain like a blotter. The bluestem grasses of the Flint Hills section--rising tall as a man on horseback where conditions were most favorable--shattered heavy summer and autumn rains into a fine dew gently falling upon the earth, and easily absorptible by it. A thick dead residue of earlier generations of plant life, and a tangle of living roots, tied down the soil and enriched it. Animals and insects were all involved, with these plants, in a precise system of checks and balances. Fremont writes in the early 1840's of "elk...frequently seen on the hills" of eastern Nebraska and of "frequent groves of oak tenanted by flocks of turkeys." West of the Little Blue "now and then an antelope bounded across our path, or a deer broke from the groves." He also speaks of elk and antelope, and of buffalo, along the Smoky Hill and the Republican in what we've viewed as the *middle* and *western* landscapes of the basin.

This life-balance did not, we repeat, prevent erosion nor floods nor occasional pollutions of streams by the dung and dead carcasses of animals. There was even some natural pollution by salt brines in central Kansas. But erosion under these virgin conditions was slow; floods were probably less frequent and violent than they now are; and seriously polluted streams formed but an infinitesimal fraction of the total surface water of the basin.

Then came the white man, with his plow and his axe and his vast destructive carelessness. He took much from the earth, and from the waters flowing across and under the earth--and he gave little back in a life-nourishing form. He plowed up grasslands, cut down woods, and started living on the fat capital of the soil instead of on the interest, as other life had done. He built towns along the streams, and instead of returning his organic wastes to the soil as other animals had done he flushed them into rivers which were often (by reason of their increased silt-load) ill-equipped to digest them. He drained water from the rivers, and from the ground through wells, for irrigation and domestic and industrial purposes, and then increased the menace to his own health while reducing his own recreational facilities by pouring into these same waters his industrial wastes. The inevitable consequence was a complex of problems in water and soil economy, increasingly serious and increasingly difficult to solve.

In short, as we view in historic perspective our use of water and soil in the Kansas River Basin, we see little evidence of that "just law" which is "right reason in agreement with nature." Instead we see repeated again and again the error of assuming that nature will suspend her laws for our convenience, or passively submit to legislation by men who have failed to consult her requirements. Slowly, painfully, and imperfectly, the recognition has been forced upon us that we ourselves are elements of the watershed, involved in a natural process, and that we can prosper through the long run only by adapting our practice to nature's precept.

3.

Two Sources of Water Law

This lesson is nowhere more clearly demonstrated than in our experience with man-made laws governing water use. Here we find that solid connecting link, to which reference has been made, between ancient Rome and our particular problem of stream pollution in the Kansas River Basin. If only we had regarded our region in the light of Roman experience, when first we came here! We might then have avoided those legal ambiguities and outright contradictions which enabled generations of lawyers, all across the Great Plains, to prosper out of litigation concerning water rights--while the rest of us fussed, and fumed, and paid the costs....

The Imperial Romans, law-givers to all after-ages in the Western World, themselves derived much of their law from the Egyptians, the Medes, and the Persians. This seems particularly to have been true of their water laws. All of these earlier peoples, be it noted, inhabited countries where water, by its scarcity, was a precious commodity. None could depend upon rainfall for the growth of crops. All land between the Tigris and Euphrates was intersected by irrigation canals from the earliest dates of recorded history; Egypt depended then as now upon annual innundations by the Nile; and all the lower plains of Iran were desert where irrigation was not practiced. Inevitably this scarcity of water, and the necessity for precisely defined rights in the use of it, were reflected in the body of law which slowly developed and which the Romans adopted, added to, and clarified.

The history of Herodotus reveals that, as far back as 2300 B. C., governments of subhumid lands faced complicated problems of water use, and solved them in ways which led toward later Roman doctrine. A King of Persia, writes Herodotus, had built a dam without sufficiently consulting the needs of farmers downstream. The farmers "who before were in the habit of using the water, not being able to use it any longer, were reduced to great extremities." At last they took their wives and "standing before the king's palace, raised a great outcry," to which the king responded by ordering that "the gates be opened toward those lands that were most in need; and when their land was satiated by imbibing water, these gates were shut, and others were opened toward those next in greatest need." This solution faced realistically the fact that consumptive use of a limited water supply by one person inevitably reduces its use by others; it also, by calling for best use through the satisfaction of "greatest need," defined an equitable goal toward which those who shape water policy are still struggling in the American West. The difficulty lies, of course, in the definition of "greatest need." It was a difficulty so great that the Romans, a hard-headed race, substituted temporal priority for need in their basic determinations of water rights.

Thus developed the Roman doctrine of prior appropriation, expressed in the oft-quoted maxim of "qui pior est in tempore, potior est in jure." We translate it freely as, "First in time, first in right." Roman civil law ordained that "ancient water rights, established by long ownership, shall continue to the individual citizens, undisturbed by innovation," and that if a flow of water through certain places "is according to custom and shows usefulness in irrigating certain tracts of land, no innovation against the old form and established custom will be permitted."

But this right by temporal priority was not unqualified in Roman law, which also embodied some elements of "best use" or the satisfaction of "greatest need" in the determination of water property. The law proclaimed that "it is not the acreage, but the use to which water is put, that measures the right to the water." In other words, priorities in time were modified by priorities of uses in the Roman definition of rights. The law ordained that water for domestic use had the prior right, that water for livestock and private gardens was next, that water for fields came third, and that water for mining and mechanical purposes came last. Thus if two men had the same right in time to a severely limited water supply, he who would use it for domestic purposes was given preference over him who would use it to water livestock; he who would water livestock had preference over him who would irrigate fields; and so on.

The Roman laws survived, piecemeal, the collapse of the Roman Empire. They were preserved in partial operation by the Arabs while Western Europe went through the Dark Ages, and they provided the bases for legal codes of new European nations when these assertive Sovereign Powers rose up, bloody-handed, out of the creative chaos of the Rennaissance. Having been developed by and for subhumid lands, the Roman water laws in particular survived in Spain, and they were translated into New World terms by the Spanish conquistadors whose 17th century conquests included what is now California, Arizona, New Mexico, Nevada, Utah, Texas.

These Spanish-Roman laws were thus to some extent operative in the California where John August Sutter maintained his fort in the early 1840's, a California then part of Mexico, and they seemed well-suited to the needs and the sense of justice of squatter gold miners who rushed by the thousand to the newly-acquired United States territory in 1849, after those stupendous discoveries at Sutter's Mill on the American. It was out of litigation involving these miners that United States courts first recognized the doctrine of prior appropriation. As interpreted by the courts in those early cases, the doctrine had three basic elements: First, the prior right of discovery; Second, the retention of this right by exercise of it; and, Third, the forfeiture of the right by failure to exercise it. Applied to miners, the doctrine insured the right to divert streams for mining purposes. Applied to agriculture, later on, it insured the right to divert water for irrigation purposes.

But in California--and later, in the Plains States--this rule of prior appropriation, this law out of warm dry Southern climates, met head-on a wholly different kind of water law, originated in the cool and humid North. This was the famed riparian doctrine of English common law.

It had developed, of course, under conditions vastly different from those which prevail through most of the Mediterranean world and the American West. It had developed in a land with an abundance of water and which therefore faced no necessity for extensive stream diversions to irrigate agricultural lands. In terms of their uses, English streams were regarded as sources of drinking water; as sources of water power; as conveyors of commerce (you'll recall the royal protest in 1372 that excessive dumping interfered with navigation up the Thames); as areas of sewage disposal; and as areas of recreation (punting and fishing have ever been favorite pastimes of Englishmen). In an environment not overpopulated, as England was not when her basic laws developed, none of these uses is such that its exercise upstream must deny absolutely its exercise downstream. The water which goes over dams and turns the wheels of industry is not thereby affected in quantity or quality. Boating or fishing do nothing to injure a stream. This leaves such matters as waste disposal and the use of water for livestock and domestic purposes to be cared for, and the English common law did so by ruling that the owner of riparian land--that is, land contiguous or abutting upon a natural stream--is entitled to have the stream flow by or through his land undiminished in quantity, except for domestic and livestock uses, and unchanged in quality.

Explains a report to the Governor of Kansas, in 1944, entitled "The Appropriation of Water for Beneficial Purposes:[1]

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[1] Subtitled "A Report to the Governor on Historic, Physical and Legal Aspects of the Problem in Kansas", prepared by a committee appointed by the Governor to investigate these matters.

"Under the common-law doctrine the right to use stream water is regarded as real property and entitled to protection to the same extent as other property.... (It) arises by operation of law as an incident of the ownership of land, of which the right is an appurtenance.... The right to the use of water from watercourses by contiguous landowners results solely by reason of location, and regardless of relative productive capacities of such lands or uses. The right attaches to the land at the time such land passes to private ownership. It is coequal with the right of every other riparian owner on the stream regardless of the relative dates on which the several tracts passed into private ownership."

This gives an idea of what you're up against when lawyers "interpret" doubtful laws. It is composed in a prose style having as its basic motive, one suspects, a desire for further lucrative litigation. (What, for instance, does "contiguous landowners" mean? Are the owners contiguous? or is their land contiguous? Or does our lawyer friend mean that the land is in actual contact with the watercourse?) But you may be able to perceive, through a muddy stream of words, that water rights, under English common law, need not be exercised in order to be retained. Such rights are not created by use, nor forfeited by nonuse.

It is a doctrine neatly consistent with the English soil and climate. It is no less consistent with the historic English character. It mirrors a typically Protestant-Capitalist conception of private property as the basic element of justice and freedom, and of freedom itself as a form of property, a private possession of the individual person rather than a function of organized groups. Liberty, so conceived, is quite largely definable in negative terms: it is an absence of restraints upon the individual, a freedom from external compulsions, an insurance against invasions of privacy. And this being true, the common law with its riparian doctrine suffered no sea-change as it crossed the Atlantic with the Pilgrim Fathers. Its rather atomistic individualism was embraced without question by men whose very voyage was a protest against government regulations, and it found on the Eastern seaboard a climate which, if more severe than England's, was no less congenial to water laws that assumed an abundant water supply. The New Englanders need make no greater nor different demands on their rivers than their forefathers across the seas had done.

But when in the 1850's a later generation of Puritans were swept westward to "Bleeding Kansas" on a tide of Abolitionist sentiment, the riparian doctrine which they carried with them ran into difficulties--the same difficulties California was experiencing as she sought to maintain the riparian and appropriation doctrines side by side. In 1855, the first territorial legislature of Kansas adopted the common law of England, and in the 1860's the State legislature reaffirmed it. In Nebraska, the common law was not included among provisions of the State Constitution, but was almost immediately adopted by the legislature. And for the first few years, when rivers were still used primarily for navigation and the turning of water wheels, court decisions sustained and even strengthened the riparian doctrine. In the 1870's, however, the tides of immigration swept out onto the High Plains, and there began the long and painful process of adjusting written laws to physical realities.

Here was a land of little rain, of low water tables, and of shallow streams which sometimes sank out of sight in their sandy beds. Here water was so precious that individuals could no longer be independent of one another in their use of it. Raw sewage disposal in streams of small and intermittent flow inevitably created public nuisances, if not dangers downstream. Irrigation upstream might prevent irrigation, or other water uses, downstream. Even domestic and livestock uses of a stream by one man might deny such uses to his downstream neighbors. In other words, streams could no longer be neatly divided into segments of private property; the equitable requirement on which such rights rested--namely, that the stream must flow from one riparian "owner" to another without diminution in quantity or quality--was impossible.

So bit by bit, in court case after court case, the riparian doctrine was modified until at last, by legislative action in both Nebraska and Kansas, it was frankly rejected and replaced by the doctrine of prior appropriation. Colorado, the third State involved in the Kansas River Basin, escaped many of these difficulties by adopting the appropriation doctrine to begin with, making it a part of the State Constitution.

4.

An Emerging Concept: the Watershed as Organism

This shift from the riparian doctrine to that of prior appropriation removed a principal legal obstacle to the maximum or "best" development of available water supplies. In subhumid areas, such development requires a community action. Irrigation requires that reservoirs and diversion dams be built, and systems of canals. Sanitary sewage disposal often requires that sewage treatment plants be built. In drouth years, as individual wells go dry, even the supply of water to farmers for household and livestock use may become a community endeavor. Hence, so far as water use is concerned, "freedom" can no longer be meaningfully defined in terms of exclusive individual "rights." It becomes a group concern, a function of community action, and can be maintained only through practical democratic planning in which the watershed as a whole is considered.

Thus we return to the lesson suggested by our blurred snapshots from history--namely, that the river is an organic element of a watershed. Its uses, its problems are all interrelated, being aspects of the total watershed as problem; and they must be considered in terms of the organic whole. Any attempt to solve piecemeal the problems of stream pollution, of irrigation, of flood control, of downstream navigation, of recreational development--any attempt to solve these as though they were separate problems--is doomed, by the law of nature, to ultimate failure....

It has been remarked in passing that we Americans, like the Imperial Romans, are a remarkably unphilosophical race. Justly proud of our great technical and administrative abilities, we dislike to be reminded that engineering, and administration, and business enterprise have no purpose or value in themselves: they are means to ends which are purposes and values: and in consequence we are much better at building huge dams, for example, than we are at deciding whether those dams ought to be built. In other words, we're "practical" men--impatient of "mere" theory and of large generalizations. We distrust those abstractions which are the materials of free speculation, and regard metaphysics as useless if not actually "silly."

"These philosophers!" a typical college president said to me one day, and with considerable disgust. "All they do is play around with words!"

In view of this attitude, it is interesting to note a curious, highly significant parallel between the kind of thinking done by contemporary philosophers as they concern themselves with abstract problems of permanence and change, and the kind being done by leading engineers as they concern themselves with concrete problems of river development. The most abstract metaphysical speculation and the most concrete practical experience both point in the same direction. They seem to lead to precisely analogous conclusions.

To the metaphysician, the river generally presents itself as metaphor. "You cannot step twice into the same river," wrote Heraclitus of Ephesus some 500 years before Christ--and philosophers ever since have used the river as a symbol of Change, of flowing Time, of a continuous flux of reality. As the metaphor is extended, the solid land through which the river flows becomes symbol of the Permanent, the static element by which change is measured, the Eternal which is out of Time altogether. Almost the whole of modern philosophy, up until very recent times, can be divided into two seemingly hostile camps by virtue of the relative emphasis given to one or the other of these two polar concepts.

Those who stress the river, regarding Change as the essence of reality, are generally mystics of one sort or another. They doubt the accuracy of logic as a guide to ultimate truths, because the logical intelligence "stops the flow" of reality and divides it into artificial static segments. More accurate in the realm of ultimates, they assert, is intuition, operating in flashes of felt truth which stimulate and provide the substance of all creative thought. Such philosophy is sympathetic to theology; it is not uncompromisingly averse to assigning to acts of Faith a status "superior to acts of Reason. On the other hand, those philosophers who stress the land: the permanent, the solid, the eternal: are generally rationalists and, quite often, materialists of one sort or another. They regard logic operating on sense-experience as the best test of truth, if not the only guide to it; they assert the feelings to be very dangerous guides indeed; and they sometimes lead the way toward an arid intellectualism, a realm of cold logic utterly devoid of living values.

Implicit here are the oppositions which so tragically divide our world. Here, in an age which goes to extremes, are implied the savage wars of religion vs. science in education, of emotion vs. intellect in the individual soul, of fascism vs. communism in European politics, of the mysticism of the East vs. the intellectualism of the West in the new battle for the world. Implicit, too, is a recognition of the goal toward which we must proceed if we are to survive as a world civilization. Our great problem is one of finding common denominators of the extremes and thus modifying them; our ultimate goal is an organic unity of seeming oppositions, which they are recognized as separate aspects of a single reality in so far as they have any validity at all. Hence we find emerging, as the most representative philosophic effort of our time, systems of synthesis and organism. F. S. C. Northrop writes a symptomatic book entitled THE MEETING OF EAST AND WEST, in which his whole purpose is to fuse the "aesthetic component" of the East with the "theoretic component" of the West to form a "higher" synthesis. And A. N. Whitehead, perhaps the most powerful philosophic mind of the century, fuses the mystical and logical approaches to reality in what he calls "the philosophy of organism."

Now to the engineer, the river presents itself as a practical problem.

It is an obstacle to be bridged, a channel to be dredged, a potential flood to be checked, a source of water to be developed for industrial and agricultural and sanitation uses. But here, too, we find an extension of the original proposition. The land becomes involved with the river. And here, too, in the realm of the concrete and particular, we find a sharp division between those who place their major emphasis on the flowing river and those who most emphasize the solid land which the river drains. Oppositions arise between those primarily concerned with flood control and navigation, and those primarily concerned with agricultural irrigation—the former thinking primarily of the river as problem and the latter thinking primarily of the land as problem. In terms of flood control itself, there are oppositions between those who emphasize land use (i. e., upstream soil and water conservation) and those who emphasize river development (i. e., big dams downstream). It is interesting to note Bernard deVote in HARPER'S Magazine, applying the very language of our philosophic discussion to the above engineering oppositions. Proponents of our present big dam program in the Missouri Valley are, says he, practicing "engineering mysticism."

But the point is that a solution to this practical problem of land vs. water seems, as we've said, precisely analogous to the solution of the abstract problem of permanence vs. change. It, too, requires the discovery of a common denominator of the extremes--a physical one, this time. It requires a concrete realization that the seemingly different (and opposed) elements are actually organically linked. This being so, an exponent of pure a priori reasoning might expect to find a continuous physical reality joining land and river, blurring out of existence any sharp distinction between the two--and, sure enough, this physical reality does exist. It is water, the element common to both river and land. Indeed, from one point of view, the only difference between river and land is in the proportion of water to solid materials, the river having a higher percentage of water per unit volume--and this difference is reduced as stream turbidity increases. The Missouri River, for example, was accurately described by Father Membre as "clear mud", and a contemporary writer[1] has described it as in reality three rivers--one of water, one of silt, and one of sediment.

Russell Lord, in his introduction to TO CLEANSE THE POTOMAC (Public Health Service publication_____), sums up our conclusion as follows:

"We like to think of 'bodies of land' and 'bodies of water' as though they were separate, but they are not. There is really no such thing as dry land anywhere. A web of water, aboveground and underground, encircles the Earth, and thus, visibly and invisibly, the ends of the Earth and all forms of life are linked."

The conclusion has clear practical implications. It implies that ground and surface water must be considered as a single element, and used in accordance with a single water policy, in such subhumid areas as the Great Plains. This point is made by the report to the Governor of Kansas previously quoted, THE APPROPRIATION OF WATER FOR BENEFICIAL PURPOSES. Says the report (pages 11 and 16):

"The source of all the surface and ground water supplies in the State is the rain which falls on the land. A portion of the rain runs off directly into the streams, constituting the more fluctuating part of the stream flow. Another portion, entering and percolating through the soil, joins the water table and starts moving slowly but continuously toward an outlet into some stream, the flow of which it helps to maintain. Such water constitutes the more regular and stable part of the stream flow.... The Committee feels compelled... to point out that the source of both water in streams and in... underground reservoirs is the same; that water used from one is not available for use from the other; that the State cannot wisely have a system of water rights for surface water and none for ground water or one system for surface water and another for ground water if there is to be orderly development of the water resources of the State."

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[1] Rufus Terrall, The Missouri Valley, New Haven: Yale University Press, 1947. Page 91.

And so we see again the emerging concept of the watershed as organism. All roads, practical and theoretical, lead toward it. Even technicians whose highly specialized concern is with sewage treatment are realizing that their specialty cannot be successfully dealt with in isolation from other watershed concerns. Write Karl Imhoff and Gordon Fair in their authoritative book, SEWAGE TREATMENT[1] (page 2):

"Sewage treatment is but one of many factors in a true and full economy of water. This should be appreciated by all who are concerned with the disposal of sewage and industrial wastes but particularly by central river authorities.... The engineer charged with the design of a sewage-treatment plant can best meet his responsibility to the individual community that he serves by taking a broad view of the regional problems involved."

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[1] New York: John Wiley and Sons, Inc., 1940.

Part Three

THE EVOLUTION OF RIVER PLANNING

1. Of Flood Control and Navigation
2. What About Irrigation?
3. The Wedlock of Pick and Sloan: Holy or Unholy?
4. Of Public Health and the River

THE EVOLUTION OF RIVER PLANNING

1.

Of Flood Control and Navigation

The Kansas River Basin is a sub-basin of the Missouri Valley. Ultimately all its runoff flows into the Missouri River; ultimately all its water problems are recognized as Valley problems. And of the latter, the most spectacular was forecast by the very manner in which the Missouri was discovered. Marquette and Joliet did it by ear. They heard the river before they saw it--and both sight and sound were terrible.

On that June day of 1673 the two French Jesuits were already, as we've observed, in an apprehensive mood. The sight of those huge painted gods on the rock cliff, savagely conceived and brutally executed, had strangely disturbed their piety. When a vast roaring sound reached their ears, growing steadily louder as they moved downstream, they began to proceed very cautiously indeed. They believed they were approaching a rapid, or perhaps a waterfall, and they probably paddled their canoes close to the river bank. Indications are that this bank was on what is now the Missouri side of the Mississippi, for they were nearly swamped when they moved suddenly abreast the mouth of a river unlike any they, or perhaps any other European, had ever seen. The sight confirmed the terror of the sound, the event was quite as dreadful as its portent.

Wrote Marquette: "An accumulation of large, entire trees, branches, and floating island was issuing from the mouth... with such impetuosity that we could not without great danger, risk passing through it." But pass through it they did, narrowly escaping death--and the Mississippi they travelled was no longer a river immense but clean. It was all stained with mud, threatful with driftwood....

The story of the Missouri thus begins with a "June rise." It was more severe than most, judging from the account, but no more severe than has occurred many times since settlement began. Undoubtedly this first recorded flood was formed by a coincidence of two towering crests, one piled on top of the other. The first of these was shaped in the river's upper system where melting ice and snow, pouring down the mountains and off the plains, had swollen all the streams. Inexorably, this crest flowed southeast to encounter crests which had flowed almost due east, having been shaped by heavy rains in the areas drained by the Missouri's lower system, including particularly the Kansas River Basin. The two floods together poured out over flood plains where today lie cities, and scores of towns, and a great wealth of farms.

All of the more disastrous floods on the lower Missouri have been so formed, and the list of them is long and depressing.

The first of which height records were kept has already been mentioned: the tremendous flood of 1844. It caused relatively little damage measurable in monetary terms, for most of the country it overran was wilderness, and the remainder was sparsely settled. But were a flood of similar proportions to occur today it would cause at least $100,000,000 of damage to Kansas City alone, according to the most reliable estimates. Disastrous enough to that city was the flood of 1903, caused by a high crest on the Kansas running head-on into a Missouri already out of its banks. The latter was abruptly raised some 14 feet above flood stage. Stockyards, railroad freight yards, packing plants, mills--the whole industrial center built on the wedge of flat lowland bounded by the two rivers--lay under deep and turbulent waters. Eight thousand freight cars were submerged; 23,000 people were homeless; and total damage was estimated at $22,000,000.

But this, perhaps the most famous of the Missouri floods, was little if any more disastrous than several others. In 1881, 1903, 1908, 1909, 1915, 1927, 1935, 1942, 1943, 1945, and 1947--in 12 years out of 66--high floods occurred. Those of 1942, 1943, and 1944--the most destructive three-year period in the river's history--caused damage estimated at more than $150,000,000 through the great Valley as a whole. The 1943 flood covered 2,260,000 acres and ruined some $40,000,000 worth of farm crops; it did an estimated $65,000,000 of damage altogether. The 1947 flood caused an estimated $111,000,000 of damage.

Within the Kansas Basin, the two largest cities are Kansas City, Kansas, with a population of 147,000, and Topeka, the Kansas capital, with a population of over 87,000. Both contain valuable property concentrated in areas vulnerable to floods from the Kaw, and they sustain the greatest damages when the great floods come. They are not, however, the only Basin cities seriously threatened. Floods are frequent at Manhattan, a city of 17,000 at the junction of the Kaw and Blue; at Junction City, with 11,000, where the Republican and Smoky Hill come together; at Salina, with 25,000, on the Smoky Hill; and in a dozen communities along the middle and lower portions of the Republican. To the Republican, indeed, goes the cruel distinction of having killed more people at one swoop than any other stream in the Kansas system. One hundred people drowned along the Republican in 1935 when a wholly unheralded 15-foot wall of water came roaring down the channel, submerging great acreages of farmland in a few minutes and destroying $9,000,000 of property.

Small wonder that the first loud demand for Missouri River development was essentially a negative one, made chiefly by cities. Stop this repeated flooding of urban areas! Keep the river away from our doors! Do whatever is necessary upstream to protect the wealth concentrated downstream! Kansas City, the most vulnerable to floods of all the Valley's large towns, was the most insistent in these demands, but other downstream towns joined in right heartily.

In response, one of the first great river engineering efforts was devoted, not to harnessing the river's energies, but to walling them away from areas where, unloosed, they wreaked the greatest havoc. This meant building levees. Some $55,000,000 had been spent, up to 1945, on levees in the Missouri system, and while they did some good the final results were far less than satisfactory. For one thing, the Missouri and its tributaries carry enormous amounts of silt and sediment; 100 million tons of silt are poured by the Missouri into the Mississippi each year, on the average; and deposits of these keep raising the river beds. Flood control then requires an equivalent raising of levee heights--and each increase in height means greater risk of structural failure. Furthermore, the levees prevent the river's normal horizontal expansion in time of high flow, and this means, of course, an increased vertical expansion. "The confinement of flood flows by levees has substantially raised the flood heights," reported General Edgar C. Jadwin[1], then Chief of the U. S. Army Corps of Engineers, after the tragic 1927 flood on the Missouri and lower Mississippi. And the 1927 disaster destroyed popular as well as technical faith in levees as (by themselves) controllers of floods.

The effectiveness of levees could be increased somewhat by channel straightening, and a good deal of this was done by Army Engineers. More is contemplated. By ironing out some of the channel kinks, engineers enable the river to discharge more rapidly its burden of water, thus reducing the chances of a piling up of flood crests where tributaries join the main stem. But, obviously, a truly adequate control requires, among other things, a group of mutually sustaining reservoirs. Dams are needed behind which surplus water can be piled up until such time as river channels can safely carry it. And to the construction of these the engineers now turned. Flood control gave way to flood prevention, in long-time river plans.

The first big flood control reservoir was formed by the Fort Peck dam across the Missouri in Montana. Completed in 1939, at a cost of $130,000,000, it is the largest earth-fill dam in the world. It is four miles long, close to a mile wide at its base, and rises to a maximum height of 250 feet above the river bed. The lake forming behind it is the second largest reservoir in the world, spreading across 245,000 acres and having a 1,600-mile shoreline. But a glance at the map will reveal that this reservoir, vast as it is, is relatively a mere speck on the surface of the Valley, and it lies far northwest of the portions of the Valley, the North Platte and Kansas Basins, which have the heaviest rainfall and produce more than half of the downstream floods. Much, much more is needed--and much, much more is planned for.

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[1] Quoted by Rufus Terrall in his The Missouri Valley, New Haven; Yale University Press, 1947.

Dam and levee building has not been sparked by flood control needs alone. Another major motive has been the desire to maintain, or create, a navigable channel from Sioux City down 815 miles to the Missouri's mouth. At a cost estimated at $300,000,000 (it's difficult to assign exact costs to any one use in such projects), a six-foot channel was completed to Sioux City in 1940, and the Fort Peck reservoir is part and parcel of this development scheme, too. The six-foot channel was not completed, however, before it was generally deemed to be obsolete. A nine-foot channel was demanded in order to avoid unloading and reloading barges where the nine-foot channel ends, and this project was authorized by Congress in 1945. There now appears to be inevitable a demand for a 12-foot channel all the way to Sioux City, to match those being built in the Ohio and Mississippi, the argument being that otherwise freight will have to be shifted from 12-foot to nine-foot barges at Kansas City, thus boosting shipping costs to excessive heights.

Estimates are that a nine-foot channel will (or would) cost at least $222,000,000. A 12-foot channel would cost, of course, a great deal more. The question of whether such expenditures can be justified in terms of long-time public benefits is a tangled one which has aroused a good deal of heated controversy. Certainly maintenance costs will run very high. Nevertheless, the big plans of the Army Engineers have marched forward, fed by Congressional appropriations through the omnibus River and Harbors bills. New levee walls have been raised, wing dikes have been thrust out from the banks, stone and willow-mattress riprapping have been laid down to reduce bank erosion, piles have been driven deep into the river bed, dredging operations have continued, and all this has been done in recent years, according to a master plan which in the early 1940's was given a name. It was the Pick Plan, christened after Col. (now Major General) Lewis A. Pick, who first crystallized Army Engineer plans into a Valley-wide program. Since the Engineers had been assigned primary responsibility for navigation and flood control, the Pick Plan was primarily concerned with river development toward these two ends. It originally called for construction of 22 dams located where they'd do most for navigation and flood control; and some 1,500 miles of levees. A double line of the latter would be built from Sioux City to the south, enclosing a mile wide strip below Kansas City.

The fact that a single Federal agency has charge of both flood control and navigation is fortunate. The bureaucratic squabble which would certainly arise if two competing agencies were involved can here be avoided. Nevertheless, there are those, inside and out of the Corps, who see conflicts in actual fact between the two kinds of river development. Flood control, they assert, has had its effectiveness reduced by channel developments thus far. The Engineers, they go on, made a mistake when they assumed that narrowing the river in order to increase channel depths, and straightening some of the kinks, would speed the flow sufficiently to scour the bottom, thus reducing silt and sediment deposits. The scouring, it is alleged, has not sufficiently occurred.

Those making this argument cite figures on river flow in support of their positinn. The Missouri Farmers Association, for example, had read into a Congressional committee record (Senate Hearings on S-555, 1945, pages 102-105) charts purporting to show that at Hermann, Missouri, the river could carry 316,000 cubic feet of water per second without flooding in 1928-31, whereas in 1942 it wouldn't carry more than 193,000 c.f.s. without flooding and in 1943 it flooded when the flow was more than 210,000 c.f.s. Navigation developments made the difference, the Association claimed. Other studies, conducted by the Regional Committee for the Missouri Valley Authority, have been reported to support this claim. The Committee said flatly: "The channel has been narrowed and its carrying capacity reduced...." A Public Affairs Institute pamphlet entitled THE BIG MISSOURI, Hope of Our West[1] sums up: "The result (of navigation development) has been that more millions of dollars of flooding damage was done in the Valley in 1947, with less peak water than in previous floods."

2.

What About Irrigation?

The navigation vs. flood control argument, however, pales to insignificance when compared with the argument of navigation-and-control vs. agricultural irrigation. This latter has been exacerbated by the fact that primary responsibility for irrigation developments in the Valley is assigned to the Bureau of Reclamation of the U. S. Department of the Interior--and this bureau competes bitterly with the Army Engineers for Congressional appropriations. It is thus difficult for a disinterested observer to determine how much of each agency's planning and propaganda is motivated by a sincere and scientific concern for Valley welfare and how much is motivated by crude bureaucratic jealousies.

Essentially the quarrel (for it has often amounted to that) is over water. Is there enough water in the Missouri Valley for both the Reclamation and Army Engineer programs? The Engineers, though hedging their answer with many crucial "ifs," have been inclined to say "yes." The

Bureau of Reclamation--at least until recently--has been inclined to answer "no." And how much Federal water development should aim toward hydroelectric power? The Army Engineers were notably vague in their first answer. The Pick Plan said that electric power would be developed, but it was not specific as to the amount. The Bureau of Reclamation, on the other hand, presented a definite figure. This agency has long engaged in public power developments: in connection with its 127 completed dams, 46 power stations send electricity along 6,000 miles of Bureau-built power lines. It now proposed to build 17 new power plants generating a total of 758,000 kilowatts[1] with an annual value of $17,000,000. The proposal was part of the Bureau's Valley Plan.

For Reclamation, too, had a Plan: the Sloan Plan, after engineer W. G. Sloan, assistant chief of the bureau's Billings, Montana, office. It called for 90 dams located where they'd be most useful for irrigation purposes--that is, adjacent to fertile irrigable land--and for a system of ditches and diversions capable of watering 4,700,000 dry acres. This would bring to 10,000,000 the total number of acres irrigated in the Valley. It also called for supplemental irrigation of 420,000 acres above Sioux City, where more water is needed. Altogether, the Bureau estimated that 9,222,000 net acre-feet of water would be required each year to service the entire scheme above Sioux City. There are signs, however, that more than this might be demanded by farmers, either because of an exceptionally prolonged or severe dry cycle or because ditches are extended to new fertile acreages. The acre-foot figure, be it noted, is net. It represents water that will not return to the river as surface drainage; the bulk of it will go, instead, into living vegetation.

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[1] The Federal Power Commission has estimated that 3,000,000 kilowatts of hydroelectric generating capacity could be installed in the Missouri system.

Can this amount of water be so used without endangering the $222,000,000 navigation program? During a wet cycle it could be, without doubt. But during a dry cycle, such as occurred in the 1930's, no one knows for sure. It is estimated that, between 1929 and 1940, the river produced on the average about 16,200,000 acre-feet a year above Sioux City. This can be augmented by water stored during wet years behind the contemplated dams. There will be some 84,600,000 acre-feet of water storage space in the reservoirs, according to present plans, but 10,000,000 acre-feet of this must be kept empty to absorb floods. Thus 74,600,000 acre-feet of actual water will be available at the end of a wet cycle to do the navigation and irrigation jobs during the dry period. Now when the Engineers presented to Congress their figures on a six-foot channel, they estimated that a flow of 22,000 cubic feet per second would be needed at Sioux City. They made no exact estimate of what a nine-foot channel would require, when that proposal was before Congress, but the Reclamation people said it would require 30,000 cubic feet per second at Sioux City. This is equivalent to 14,500,000 acre-feet of water per year, "without any allowance for winter flow for sanitation purposes or waste".[1] Add up the figures: 9,222,000 acre-feet for irrigation; 14,500,000 acre-feet for navigation: and you get a grand total of 23,722,000 acre-feet per year. The river, as we've said, produces 16,200,000 acre-feet per year during a dry cycle, or did during the 12-year period from 1929 to 1940 inclusive. The difference of 7,520,000 acre-feet per year must come from the storage reservoirs.

By this figuring, if a dry cycle lasts more than seven years there just isn't enough water to take care of both navigation and irrigation, as these two developments are now planned. Either navigation or irrigation--or both--must suffer....

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[1] The Big Missouri, Op. Cit.

Now certainly it's possible that the above figuring, and its unhappy conclusion, are incorrect. Controversy rages over the subject, and some technicians assert that the picture here drawn is badly distorted. But the point is that this sort of question is a question of fact, and the most common of common sense tells us that matters of fact are not proper subjects of controversy. One can argue sensibly over interpretations of facts. One can argue over who should get the water if there is not enough to go around. But one can not argue to any reasonable effect over whether or not enough water is available. Either it is or it isn't--and the only way to find out is to take a careful, scientific look-see.

Admittedly, this is not easy to do in the Missouri Valley. Rainfall fluctuates astoundingly within small areas, with the result that the records of the Weather Bureau, whose reporting stations through this region are widely scattered, are highly inaccurate guides to the total amount of precipitation in the Valley. For example, reports Rufus Terral[1], "Mitchell and Scottsbluff, in western Nebraska, are only eight miles apart, yet each town has had nearly 1.5 inches of rain within three days' time during which the other had no rain at all." This extreme variability from mile to mile means that many local rains go unreported by the Weather Bureau, while other strictly local rains are reported as general. It is therefore impossible to predict flood peaks, with any consistent accuracy, by projecting the available rain-gage data. Take the already-mentioned Republican River flood of 1935. Of it, the Department of Agriculture says: "The astounding peak...climbed far above any curves likely to have been projected on the basis of rain-gage records within the watershed of that stream, or of neighboring streams. Even the precipitation readings for the rain that brought on the disaster do not account for the prodigious volume of water that charged down the valley; somewhere between the established gages the rainfall must have attained intensities wholly out of line with any actual measurement." In this subhumid region, rainfall also fluctuates astoundingly from year to year in any one locality. Continues Terral: "Scottsbluff's annual rainfall was almost exactly the same in 1930 as in 1929--around 17 inches--while Mitchell's increased 50 percent--roughly from 14 inches to 21." A variation of 50 percent between one year and another means that stream flows can be accurately gaged only over a long period of time. Ten or even 20 year averages from gaging stations mean little in the western portion of the Kansas Basin, and they mean but slightly more on the lower portions of the Kaw and the Missouri. As Terral points out, the minimum flow of the Missouri was once estimated to be twice the flow which actually occurred during the great drought of the '30's.

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[1] Opus Cit.

Yes, the look-see is difficult--but it's obviously the only way we can really answer the question of How Much Water. Argument from now on until doomsday will not answer it, no matter how elequent it be or how passionate. Nor will argument answer the other questions of fact which have been raised--the question, for instance, of whether navigation developments have increased flood hazards, or the question of how much (if any) flood reduction can be achieved by soil conservation practices on the uplands. The only thing to do is go find out. Why, then, have we not done so?

A chief reason has been that the acquisition of different sets of facts is the responsibility of different Federal agencies, each with its own budget, its own specific terms of reference, and its own esprit de corps which, when it inhibits needed cooperation, does at least as much harm as good. It's clear from the above discussion, for example, that a great expansion in scientific weather reporting is needed to provide absolutely basic data for Valley engineering. But weather reporting is not the responsibility of the Army Engineers or the Bureau of Reclamation. It's the responsibility of the U. S. Weather Bureau--and any considerable expansion of this agency's activities in the region might conceivably reduce the activities of other agencies, since the total Federal budget for any one year has (even though some people don't think so) definite limits. Similarly with the U. S. Public Health Service and the U. S. Soil Conservation Service, two agencies whose data and whose planning abilities are indispensible to the wisest use of Valley water.

In recent years, however, more concerted efforts have been made to get at the facts, and to use them in integrated planning. Let us examine them.

3.

The Wedlock of Pick and Sloan: Holy or Unholy?

A chief incitement to new integrative efforts has been the pattern provided by the Tennessee Valley Authority, a pattern which is of course variously viewed but whose influence is undoubted. Some see it as a shining example for the Missouri Valley to follow--with necessary modifications. Others see it as the darkest of threats, to be avoided at all costs--including the not inconsiderable expense of lobbies and widespread propaganda. But no one seriously concerned with Missouri Valley problems looks upon TVA with indifference, nor fails to note that its undeniable successes derive, in large part, from the fact that TVA is a single agency, a government corporation set up to do a unified, multiple-purpose, valley-wide job. It is clear that the Tennessee Valley could never have been developed as it has if a half-dozen federal agencies had operated as sovereign powers on a half-dozen portions of the total Valley problem.

Seeing this, popular criticism of Missouri Valley plans became increasingly vociferous. Many and loud were the cries that important interests, carefully guarded in the multiple-purpose planning of TVA, were either ignored completely or insufficiently served by the Missouri projects of Reclamation and the Engineers. Why so little low-cost electric power in an area which needs so much? What about the use of streams and reservoirs as recreation areas? What about public health with its close dependence on safe and abundant water supplies? To what extent were these matters considered when dams and reservoirs were designed? Obviously they were not, in many cases, considered at all. And why weren't they? Because Valley development was proceeding piecemeal. Let's integrate! cried influential voices. Why not eliminate the frustrating, irritating, thoroughly wasteful interagency competitions in our own Valley? Since specialized knowledge and talent are valuable only to the extent that they are parts of a total effort, why not pool them in a single agency through which a total effort can be made? In short, why not set up an MVA?

Senator James E. Murray of Montana saw no reason why not, and introduced a bill whose passage would accomplish that purpose. His proposal was promptly supported by the American Federation of Labor, the Congress of Industrial Organizations, the National Farmers Union, President Roosevelt, the St. Louis Post-Dispatch, and most of the leading political liberals in the Valley. It was as promptly opposed by the river navigation interests, private utility corporations, many private contracting firms (TVA did its own building instead of letting fat contracts) the Kansas City Star, and most of the leading political conservatives of the Valley. The issue was joined, and the noise was great.

The immediate result could have been predicted by anyone aware of the "common enemy" device for achieving social unity: it was an abrupt marriage of convenience between the Pick and Sloan plans. However seriously Reclamation and the Engineers might disagree, they were as one in their opposition to an Authority in which their identities would be lost--and this opposition provided common ground for the so-called "Omaha Compromise" of 1944. The wedding took place just eight weeks after the Murray bill was introduced and four weeks after President Roosevelt sent a special message to Congress calling for the creation of Columbia, Arkansas, and Missouri Valley Authorities. The "vs." between Pick and Sloan was replaced, or hidden, by a hyphen: the ill-matched couple was now the Pick-Sloan Plan, and Congress subsequently blessed the union with appropriate legislation.

In effect, the new Plan, as approved by Congress, is a simple combination of the two original schemes. Altogether 107 new dams and reservoirs are proposed, including nearly all of Pick's original 22 and Sloan's original 90--and this despite the fact that, before the Omaha meeting, each agency was loudly certain that some of the other's proposals were wholly unjustified. Pick's 1500 miles of levees are included, and so are Sloan's 4,700,000 acres of new irrigation. Sloan's hydroelectric power proposals are included, and so, of course, is the virtually completed 9-foot navigation channel from Sioux City to the mouth of the Missouri. In June of 1948, the Engineers had under actual construction six reservoirs, 15 local flood protection projects, and three navigation projects at a total completion cost then estimated at $796,000,000, while the Reclamation Bureau had under construction 17 reservoirs with associated irrigation works with a completion cost of $595,000,000. Total cost of the authorized six-year program was then estimated at $6,360,000,000.

Of these vast developments, a not inconsiderable portion lie within the Kansas River Basin. A large dam at Kanopolis, Kansas, has been completed and a lake of ________ acres has formed behind it. Five other dams are under construction, four on the Republican and one on the Smoky Hill 80 miles above the Kanapolis fill. Construction of 10 additional dams has been authorized by Congress, and a still additional 18 are proposed. Altogether, if the Plan is completed, 34 reservoirs in the Kansas Basin will hold approximately 7,100,000 acre-feet of water, of which 1,130,000 will be available for irrigation and 1,400,000 are assigned to conservation. If the full planned potential is realized, more than 300,000 new acres of land in subhumid Kansas and Nebraska and Colorado will be irrigated, and ______________ kilowatts of electric power will be generated for an area now notably deficient in such power.

Helping to guide all these developments, in terms of general policy, is a Missouri Basin Inter-Agency Committee, established in 1945, shortly after the joining of Pick and Sloan. Designed to mitigate criticism of the Plan, if not to remove its basic causes, the Committee reviews problems between the various and still-independent Federal programs. It was and is a voluntary committee, originally composed of representatives of the Departments of Army, Commerce, Interior, and Agriculture, the Federal Power Commission, and five Missouri Valley State governments[1]. The first chairman was Major General Pick, who was succeeded by W. C. Sloan of Reclamation; Sloan, in turn, was succeeded by Gladwin Young of the Department of Agriculture, who holds the position as this is written. The meetings provide a forum for the 24 Federal bureaus concerned with various phases of the

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[1] State representation is rotated among the 10 States in the Valley, only five being represented at any one time.

Plan. These 24 include the Weather Bureau, the Forest Service, the Rural Electrification Administration, the National Park Service, the Soil Conservation Service, and the Public Health Service. Meetings of the Committee are public, and private citizens are free to participate in discussions. Thus, as we've said, data-gathering activities are now more extensive and better coordinated than they formerly were; and citizens of our region have, in the Committee meetings, an instrument through which to communicate their opinions and prejudices directly to those heading up the work.

By the fall of 1949, W. G. Sloan of Reclamation would announce with justifiable pride[1] that "all over the Missouri Basin construction work is proceeding at an unprecedented rate," that "practically all major features under construction are well ahead of schedule," and that "all the key structures in the program are either under way or will be started within the next year." The Fort Randall and Garrison dams on the main stem of the Missouri were "so far along," he said, "that by the year 1953 or 1954, people living along the river from Yankton to Kansas City can be assured that the disastrous floods which have been recurring so frequently of late will be a thing of the past." He added that "with the completion of the Harlan County Dam and the protection works now under way in the vicinity of Kansas City, that city can be assured of complete flood protection within three or four years."

The grandeur of this engineering stirs the imagination. It must greatly augment the wealth and reduce the flood risks of the Valley. It can hardly fail to inaugurate a new economic era across the Plains. Nevertheless criticism of the Plan, and pressures for an MVA, continue.

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[1] In a paper presented November 30, 1949, in Omaha.

For despite the attempts at coordination of the program, there are people who assert that the Pick-Sloan Plan comes about as close to a truly integrated development program as the United Nations comes to a true world government. They find Reclamation and the Engineers occupying, in the new set-up, positions almost precisely analogous to those of Russia and the United States in the UN--two great sovereign powers who, behind all the window dressing, will admit of no law but their own. They claim that the Inter-Agency Committee is about as effective a peacemaker as the UN's Security Council, and for the same reason--the Committee can act (insofar as it can act at all) only through unanimous consent of the major Federal members. Thus each "sovereign state" has veto powers, and when these are exercised on truly crucial issues (as they always are), the issues are referred to Washington. Ultimately they may go to Congress (a notorious controversy over the height of the Garrison Dam, in North Dakota, went there) and this, in view of the pressure groupings and the competing lobbies, is all-too-closely analogous to going to war. Certainly Congress is ill-equipped to solve engineering problems in other than political terms.

Among those high critical of present arrangements has been the Hoover Commission, established to study and make recommendations concerning the organization of the executive branch of Federal government. The Commission's "Task Force on Natural Resources" (Appendix L) contains a careful review of Missouri Valley developments through June of 1948. The Task Force found that "the most conspicuous missing parts" in the present plans are: "(a) A means of considering the over-all social and economic objectives of the region (toward which all present efforts should be directed); a means of evaluating the several programs in relation to those objectives; and an instrument for integrating the program on some basis other than Federal agency compromise. (b) A means of continuing consideration of regional development and conservation problems, prepared for study, recommendations, and action on them as they arise."

The Task Force found the present Inter-Agency Committee wholly unable to supply these "missing parts," and for the following reasons:

"a. (The committee) has no authority... no capacity for decision... (and) no staff for the study of problems concerning two or more of the programs.

"b. It does not have an over-all social and economic program, nor the means of formulating one....

"c....(The) committee is not equipped to carry on the continuing research in industrial engineering problems ... (needed in) a program of industrial encouragement. There is no provision for undertaking the complex task of balancing manufacturing and agriculture in the valley.

"d. The committee is not at present an agency for anticipating general problems, it is a forum for harmonizing established programs."

The Task Force did not favor establishment of a Missouri Valley Authority, however. It recommended, instead, the abolition of the Department of Interior and its replacement, in part, by a new Department of Natural Resources[1]. Within it would be a consolidated Water Development Service to administer (among other things) the present functions of the Bureau of Reclamation, the river development functions of the Engineers, and the power marketing functions of present Interior's Division of Power; and a consolidated Forest and Range Service, based upon the present Forest and Range Service, based upon the present Forest Service (now in the Department of Agriculture) and including forest and range management functions now carried on through Interior's Bureau of Land Management. "Activities dealing with harvest crops and domestic livestock on farms should continue to be handled by the Department of Agriculture," says a footnote to the report--and these activities include the erosion control work of the Soil Conservation Service. The Water Development and Forest and Range Services would be "decentralized" into regions, each region coinciding "where practicable" with river basins "to facilitate 'grass roots' decisions, interservice cooperation and local participation in planning." Further, "regional advisory committees should be set up for both Services to give full representation to State and local interests and to other Federal agencies substantially concerned."

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[1] Another Task Force, that on Public Works, recommended a Department of Works which would assume many of the same functions as Natural Resources. Either proposal, if adopted, would eliminate the Reclamation vs. Engineers friction.

Obviously, this proposed organization would avoid many of the evils of bureaucracy which now prevail in the Valley. It would also accomplish many of the positive purposes of an MVA. Whether it is actually better in all respects than an Authority is a question for the nation as a whole, and not merely for Valley citizens, to answer.

4.

Of Public Health and the River

This, then, is the bewildering complex of problems into which stream pollution and its abatement must be fitted. Whatever the final, total answer to the difficult questions we have raised, it must include the public health aspects of water use. Congress has so ordered.

Public Law 845, adopted June 30, 1948, by the 80th Congress, is an act "to provide for water pollution control activities." Section 1 declares it to be the policy of Congress "to recognize, preserve, and protect the primary responsibilities and rights of the States in controlling water pollution" but to help the States carry out their responsibilities by providing them with technical assistance and financial aid. Section 2 orders the Surgeon General (chief of the Public Health Service), "after careful investigation, and in cooperation with other Federal agencies, with State water pollution agencies and interstate agencies, and with municipalities and industries involved, (to) prepare or adopt comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries thereof and improving the sanitary condition of surface and underground waters." The key words here are cooperation and comprehensive. The latter is significantly repeated in the next sentence of the Act: "In the development of such comprehensive programs due regard shall be given to the improvements which are necessary to conserve such waters for public water supplies, propagation of fish and aquatic life, recreational purposes, and agricultural, industrial, and other legitimate uses."

What does this mean? Clearly implied is an integrated multiple-use approach to basin planning. Congress wants public health to have its proper place in such planning, and specifically orders Federal sanitation officers to regard their work as part of a whole development program. It is an indispensible part, but only a part. It must be performed in harmony with other elements of the total program. Unfortunately, the assemblage of instruments in the Missouri Basin is very imperfectly orchestrated, as we have seen. The most sanguine could hardly expect sweet harmonies to issue from instruments played, in the absence of a conductor, by men who read different arrangements of the same music--if, indeed, it is the same.

But it was hopeful to see the intent of Congress partially anticipated by the arbiters of our basin Plan. In the spring of 1948, a Public Health Service representative was included on an interagency subcommittee on basin six-year planning, and the public health aspects of water development were being given increasing practical recognition as the work went forward. Even more hopeful was the fact that an extensive water pollution investigation in the Kansas River Basin had been started a full nine months before the Water Pollution Control Act was passed, and was being carried on cooperatively by the Public Health Service (which had primary responsibility for it), the Corps of Engineers, and State health officials.

Sanitation engineers were not involved directly in design of either the Kanopolis or Harlan County reservoirs, nor did they have opportunity for effective review of the plans before actual construction began[1]. It was obvious, however--and was quickly pointed out by State and Federal public health officers--that the uses of water for drinking, for food processing, and for sewage disposal were directly affected by the quality and quantity of stream flow, and that the latter were in turn directly affected by upstream reservoir developments. Any drastic reduction in stream flow brought about by new irrigation, for example, might require that sewage treatment practices downstream be modified. Perhaps sewage treatment plants must be built where none had been needed before. Certainly the Reclamation engineers who will regulate stream flow on the Republican below the Harlan County dam must take into account the sanitary water requirements of municipalities. Recognition of this necessity sparked, in 1947, a meeting of the Engineers,

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[1] Presumably future Reclamation and Engineer designs will be carefully studied by all agencies at work on water development, while any pollution abatement works proposed will be subject to similar review. In this connection, the Hoover Commission Task Force on Natural Resources recommends that its proposed Water Development Service "review all pollution-abatement surveys and construction projects for their relationship to river development plans and projects of other purposes."

Reclamation, the Public Health Service, the Kansas State Board of Health, and the Nebraska State Health Department. From it issued a "Memorandum of Understanding" in which a cooperative investigation was ordered, effective October 17, 1947. A few weeks thereafter the actual survey began.

In accordance with the Memorandum, the survey was to include, among other things, the following: (a) Information on the extent, types, and sources of pollution of Kansas Basin waters[1]; (b) A review of existing State laws in Nebraska, Kansas, and Colorado, and pending legislation regarding pollution of public waters; (c) Data on minimum stream flows necessary below reservoirs for public water supplies and for sanitation purposes in view of present and "contemplated" pollution; (d) Data on public water supply needs; (e) A review of possible benefits to the abatement of water pollution problems by "reservoir releases" and the return of irrigation water to the streams; and (f) Recommendations and existing plans for pollution abatement. This was no small order, particularly in view of the necessity for obtaining the information as quickly as possible.

For one thing, a mass of "paper work" was necessary. Present and proposed State laws on water use must be studied; gaps in existing State legislation, and proposals for filling them, must be described; and in all this the desires and ideas of State and municipal health officers must be consulted. (The Public Health Service, it should be pointed out, is a remarkably "decentralized" Federal agency; it operates chiefly with and through State governments, primarily by means of "grants-in-aid" to State health boards.) Present and future municipal water needs must be carefully assessed. Existing stream gage data must be gathered from many and various sources, as well as data on the flows proposed in reservoir developments. And, finally, the field and laboratory work needed to supply deficiencies in pollution data must receive administrative direction. The latter task was complicated by the fact that several agencies, with differing pay scales, supplied personnel. Naturally John Doe's morale is not raised when he discovers that Richard Roe, who works beside him on the same job, receives more money simply because he's listed on a different payroll--a fact which, by itself, argues strongly for the integrated approach to basin development.

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[1] The pollution here referred to did not include that of soil erosion. It was limited to domestic sewage and industrial wastes.

Nevertheless, field work proceeded in this case with a generally high good humor. Chiefly it consisted of gathering samples at predetermined points in the streams and rivers. The samples must, of course, be gathered with a uniform precision. Calibrated jars on long chains must be lowered from bridges, or banks, to precisely assigned depths; exact temperatures must be taken; the samples must be stored in such a way as to maintain their bacterial life; and the various analyses, chemical and bacteriological, must be performed as quickly as possible.

The latter work was done in three laboratories. Samples collected from the lower portions of the Basin were analyzed at the Kansas State Board of Health laboratory, in Marvin Hall on the campus of Kansas University. The bulk of the samples collected elsewhere were analyzed in a special central laboratory established at the Smith Center Water Plant, Smith Center, Kansas. The Lawrence laboratory began receiving samples on December 17, 1947; the Smith Center laboratory began its analytical work some three months later; and the work of both was supplemented, from June through October of 1948, by a mobile trailer laboratory unit which successively operated on samples from the upper Republican and its tributaries, and samples from the Big and Little Blue sub-basins.

Altogether 4310 samples were collected and on these more than 34,500 separate chemical, bacteriological, and other analytical determinations were made. Routine analyses were supplemented by special studies of chlorides in streams, and of dissolved oxygen. Also special investigations were made of pollution from poultry dressing establishments, and of the effectiveness of selected sewage treatment plants.

Out of all this labor emerged, in June of 1949, a mimeographed report of 350 single-spaced typewritten pages, handsomely bound in red and filled with maps, graphs, and tables. It contained a detailed picture of stream pollution and its sources in this basin, as well as detailed recommendations for future abatement work and the information on minimum stream flows needed for public health purposes. Concerning this phase of Kansas Basin development, planning need not be blindly done.

Nor is this the only survey of its kind in the Missouri Valley. Before it was completed, similar work was under way in the Lower Platte River Basin. In June of 1950, a report of it (in a blue cover, this time) was issued. Shortly thereafter a "Preliminary Draft of a Proposed Report on Water Pollution" for the whole of the Missouri system was issued in mimeographed form. Thus effective consideration of public health seems insured as the several river developments continue their evolution toward an organic unity.

Part Four

POLLUTED WATERS

1. Rivers Alive--But Sick
2. Diagnosis: Method and Data
3. The Sickness of the River and the Health of Man

POLLUTED WATERS

1.

Rivers Alive--But Sick

Consider, for a moment, the intimacy of water. Herman Melville hinted of it in the opening pages of his MOBY DICK, as he told why his Ishmael went periodically down to the sea in ships.

"Say, you are in the country; in some high land of lakes," wrote Melville. "Take almost any path you please, and ten to one it carries you down in a dale, and leaves you there by a pool in the stream. There is magic in it. Let the most absent-minded of men be plunged in his deepest reveries--stand that man on his legs, set his feet a-going, and he will infallibly lead you to water, if water there be in all that region."

What is this instinctual magic by which men are drawn to water, even though they be not athirst? Why do we so often choose as our seat of contemplation the bank of a lake or stream? And what is it drives us out in boats with or without a fishing rod, and makes of swimming the most joyous of solitary exercises? Could it be the attraction of like-to-like?

Perhaps. For we ourselves are mostly water, physically speaking. "Even the Archbishop of Canterbury comprises 59 percent of water," writes Sir Arthur Shipley in his book entitled LIFE, though the proportion varies from tissue to tissue in the Archbishop, as in ourselves. Blood, of course, is more than nine-tenths water. Our kidneys are sometimes as much as 82 percent water. The average muscle is 75 percent water. Liver is 69 percent water. Even our bones, which we incline to think of as dry and solid lime, are in their living state 22 percent water. The vital interior of all cells is fluid, consisting largely of solutions of various substances in water, and through our perspiration, our moist breaths, and our excretions water is continually being lost from our bodies. Every year we replace the loss by pouring down our gullets approximately five times our own weight of water. About 6,500 gallons will have poured through our systems by the time we die, if our life span is normal--and that span will abruptly end if we are cut off, for more than a very few days, from a supply of drinkable water. It is thus no fanciful metaphor which describes man's life as a flowing stream, nor describes his body as a liquid flux contained by banks and strewn with shoals of water-permeated tissue.

Like-to-like! Observe a mountain brook sparkling in sunlight, whispering past grassy banks, laughing softly as it leaps the white stones of a rapid, roaring with laughter as it plunges down a fall. Observe a wilderness river in wooded country, more sedately flowing, faintly stained a reddish-brown with leaf mould, but remaining crystal clear nonetheless and reflecting with refreshing candour all the moods of sky. Such brooks and rivers seem alive, and in a sense they are alive. They breath air. They perspire, yielding moisture to the air. They require good water to drink if they are to remain strong and healthy. Though they are now sparkling with good health, they are vulnerable to disease, and the disease may be fatal, transforming them into ugly stinking corpses. What strange horror we then feel, looking down upon a dead body of water! It is as though a friend had died--and we had killed him!

Nor are such feelings of guilt unjustified. Almost always, the disease of the river is man, or the works of man. Too many human beings crowded upon the river are like too many hostile germs crowded upon a bloodstream, spewing poisons into a vital flux more rapidly than the flux can overcome them. Civilization can prevent this but, alas, it has not often done so. More often it has done just the opposite. Generally speaking, our industrialized cities and mechanized farms have been ministering to our desires at the expense of our natural environment, killing the latter element by element, and at an increasing tempo. Our mills digest whole forests; our plows lay bare vast slopes of soil; our mines probe the mineral guts of the earth; our factories hugely mould dead stuff into the shapes, the many thousand shapes, of our wish. And the immense wastes of these immense labors we callously thrust down the throats of our rivers. The rivers choke on them.

Consider how a river may die! Think of it now, not as a living entity, but as a complex of living entities, a vital system sustaining in its bosom myriad forms of life which are balanced one against another in much the same way as life is balanced on the (relatively) dry land. Think of it, to begin with, as a habitat of fishes--for of all the life-forms of the river, these are the most obvious to man's eyes and the most appealing of his interests.

Fish must breathe. Like men, (each of whom had once the shape of a fish in his mother's womb, gill slits and all), fish maintain their vital energies by a slow burning of tissues, a process of oxidation, and since carbon is the chief substance oxidized, fish, like men, exhale chiefly carbon dioxide. They must, then, have oxygen. It might seem that this could present no problem to creatures immersed in H_2O, a substance made up of one part oxygen to every two parts hydrogen. But water is a toughly integrated substance: breaking the link between the H_2 and the O requires a much more elaborate chemistry than any fish is capable of: so the fish must breathe in "free" (that is, uncombined) oxygen, just as men do. This oxygen is dissolved in the water, whence it has been absorbed from the air. Up to 9.17 parts of oxygen per million by weight may be so dissolved at 20° C., and a trout needs, at the very least, 5 parts per million. A trout won't flourish, however, if less than 7 parts per million are present, while a mud catfish or a carp may do very well on half that amount. It is thus obvious that anything which affects the oxygen supply of a stream affects the character of the fish life of that stream, and any drastic reduction of the former must mean a reduction of the latter. One thing which affects oxygen supply, incidentally, is temperature. The colder the water the more oxygen it can hold, other things being equal, and this is one reason why trout (the athletes of the piscatorial world) are found in mountain streams but not in the rivers of the Kansas Basin.

Not only must fish breathe; they must also eat. Otherwise they have nothing to oxidize. And what do they eat? They feed a great deal on each other, of course, big fishes swallowing little ones with a distressing lack of fastidiousness. They feed on insects which ride the surface of the water and tiny crustaceans which float in it. They feed on random bits of animal life which grow in the stream or are washed into it--bristle worms, for example, which look like earthworms and often breed in vast quantities in the oozy beds of slow-flowing rivers. But ultimately fish, like other animals, depend for food upon vegetable-life: organisms which can feed directly on mineral elements, synthesizing organic compounds out of inorganic materials. (In the process, carbon dioxide is absorbed and free oxygen expelled, thus helping to maintain or increase the dissolved oxygen content of the river.) There is a good deal of this kind of life in the ordinary river's vital system, much of it invisible to the naked eye. The amount varies inversely with stream-flow-- rapid streams have relatively little--and directly with light and temperature, up to a certain point. Photosynthesis, the process by which chlorophyll (the green stuff of plants) employs light energy in the compounding of organic tissues, cannot of course take place at all if sufficient light is not present.

Further, fish have certain standards of cleanliness. In part these are imposed by the manner in which a fish breathes. Having no nose, the fish must breathe through its mouth, the first step being the opening of the mouth and the closing of the gill covers. This done, the mouth is shut, the gill covers opened, and the mouthful of water squirted through the gill slits past delicate filaments which are chock-full of tiny blood vessels. These absorb free oxygen from the water directly into the bloodstream. Obviously the suspended solid material in a notably dirty stream may injure the gill filaments; it may even clog the gill openings; and the result in either case may be that the poor fish chokes to death. This purely mechanical requirement of cleanliness is by no means the only one imposed by the fish's nature, however. Fish may seen to us remarkably unfinicky in their eating habits; the range of their food may seem to us both queer and wide. But fish which eat filth taste of filth when we eat them, and they cannot eat just any ole thing. They can be poisoned. Sad and all-too-frequent are the occasions when some industrial plant suddenly dumps a large amount of chemical waste into a river and thereby kills every fish in it for miles downstream.

Keeping the above facts in mind, we can define almost the whole nature of stream pollution in fishy terms.

Consider, first, the effects of sewage disposal on dissolved oxygen content. All along the lower reaches of the Kaw, to take one example, are towns and cities which pour into the river their wastes: the excretions of human bodies, the refuse of food processing plants, and waters fouled by their use in industrial processes. For the most part there wastes are unstable organic compounds which have not been treated in sewage plants. The river must digest them. And how does the river do so? It dissolves that which is soluble; it breaks into fine pieces loosely integrated but insoluble materials, holding these in suspension; and it supplies the oxygen needed by the millions of microorganisms which, feeding on the sewage, transform it into a sludge no more offensive and far more fertile than ordinary topsoil. The whole process consumes oxygen. Wherever the river is overloaded with sewage, as it is along some miles of the Kaw and its tributaries, the oxygen supply is so reduced that many of what the sportsman regards as the "best" fish cannot survive at all.

Consider, second, the effects of solid materials on the river's light economy. As turbidity increases, light penetration decreases. Some years ago the Bureau of Fisheries made studies at hundreds of points on streams of the Mississippi, Ohio, and Missouri River systems, studies which including more than 5,000 determinations of light penetration[1]. It was found that light of a certain intensity penetrated a clear mountain stream to depths of 50,000 millimeters whereas that same light penetrated the Missouri River to a depth of only 84 millimeters. Turbidity, primarily composed of erosion silt but augmented by urban wastes, made the difference. Inevitably this reduction in light means a reduction in populations of the better fish. Every fisherman knows that game fish won't bite when the stream is muddied by high water, and he therefore avoids the stream at such times. If the stream is permanently muddied, the game fish retire, or die out, altogether. The whole character of the river as a vital system is changed when its waters grow opaque, and involved in the change is a reduction of the river's capacity to clean up the messes dumped into it: the microorganisms which release oxygen through photosynthesis cannot live without light, and the oxygen they would release is needed for the digestion of organic wastes. All manner of evil may safely thrive in darkness. The river becomes poisonous.

Consider, third, how the fish's food supply, and its nests and spawning grounds, are ruined as the waterr grow turbid. As shifting blankets of debris cover the bottoms of streams they smother out the organisms which normally live there and on which fish normally feed. The bed of a river like the Kaw, or the Missouri, is itself a thickly flowing syrup: it is a loose mass of sediment which pours sluggishly downstream, pausing when the river is low, accelerating when the river is high, but always denying to fish their proper homes and a fit place to lay their eggs. Moreover, "silt tends to precipitate chemical wastes, oils, and pulps dumped into streams," writes M. M. Ellis,[2] and "decomposition of these substances decreases the amount of essential oxygen available at the bottom of the stream."

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[1] Reported in U. S. Department of Commerce, Bureau of Fisheries Circular No. 7, 1931.

[2] In an article on "Erosion Silt as a Factor in Aquatic Environments," ECOLOGY, vol. 17, 1936.

Thus does stream pollution manifest itself in fishy terms. Thus may the decline in fish life measure the sickness of rivers. What is injurious to fish is, in this case and generally speaking, injurious to men (who once were shaped as tiny fish), and whatever we do to cure the stream for our own sakes will largely restore it as a habitat for fishes. So far, the curative efforts have been meager indeed compared to the river-sickness we have produced. For the most part we've treated (and inadequately) the symptoms rather than the causes of the disease.

Stand for a few moments on the bank of the Kaw at Kansas City when the river flow is normal. Watch the process of river-infection. It is appalling. The earth on which the city stands is honeycombed with tubes, and into them is rejected that which stinks and festers. Small tubes feed into larger ones, and these into still larger ones, until the largest are reached. The largest go down to the edge of the river, beneath our feet, and spew out like so many anal openings their collected filth. From the bank you can watch greasy stains, vari-colored and with globules of garbage and other solid stuff in them, streaming and spreading from each opening down and across water already brown with mud. Inorganic wastes mingle with organic ones. Here is a yellow streak of sulphur, there is a green streak of copper, beyond is a black streak of mineral oil which as it spreads becomes rainbow-hued. But bearing all these, and spreading over increasing portions of the river surface, is the film of grease. It has, alas, a certain odor.

Here we see with immediate vision what happens when the river, a vital system, is treated mechanically, as though it were a fluid waste-basket of unlimited capacity. We sense the living stream's sick rebellion against such mechanism. It suffers from indigestion, from acute constipation, and we ourselves are revolted by it. We feel personally outraged. We deplore the spectacle from the watery depths of our beings....

2.

Diagnosis: Method and Data

So far in this chapter we have been looking at the river and its pollution pretty much as artists might, defining our outward vision in terms of an inward response to it.

As artists--and each natural man *is* in this sense an artist--we are concerned with the concrete entirety of things. Artistic method, if so spontaneous a process may be called a "method," is one of *feeling* one's self into the vital heart of whatever is looked upon, realizing each object in its "unanalyzable unity." The way of art toward the outer world is contemplative, and intuitive, and determined by living values. Thus for the artist green boughs are gay, naked boughs are sad, the river rolls proudly or sullenly broods, and the gray hardness of stones is ungrateful. Our own Kaw River seemed sullen to us as we watched it from the banks of Kansas City. It seemed dangerously so as it poured its poisoned substance into the broad Missouri....

But now we must look at the river, not as artists, but as scientists. This is a very different way; it is clearly a method rather than a process.

The scientist *as* scientist is not concerned with the concrete entirety of things, but with their schematic outlines--and these are invariably patterns of possible action upon the object under investigation. His ultimate goal is not "mere" understanding, not the "meaning" or "truth" or "value" which aesthetic contemplation uncovers; rather, his goal is a definite, practical design for action. In so far as he does seek to understand, it is (ultimately) in order to act[1], and by his methods he can understand only that which is relevant to action. Indeed, he goes to great lengths to rule out "irrelevant" values, imposing a rigorous censorship on his natural impulses to insure that his discoveries are precisely limited concepts on which practical programs may be based. The scientist, then, far from looking upon objects as "unanalyzable unities," regards them as bundles of relations, and the first step of his investigation is a disintegrative one. He analyzes the whole into its parts, classifying the latter in specific categories whose basic determination (though this is often not realized) is use-value.

So it was with the scientists who investigated pollution in the Kansas River system. They looked upon the river with a measuring eye. They were concerned to see it, not as a total flowing reality, but as a succession of static moments, each moment being precisely located in the stream and each presenting to their trained vision a measurable pattern of pollution. Their first step was to "freeze" the river into 4,310 water-samples. Their second was to analyze these into 34,500 separate laboratory determinations. Their third was to combine the individual patterns of pollution thus revealed into an overall pattern for the watershed. The latter became a pattern for action. It indicated what should be done to reduce pollution and so restore to our streams some of their former health and beauty.

The yardsticks used to measure pollution, in this investigation, were various and ingenious. It might be thought that laboratory tests would be designed to measure directly the dangerous infections of the river: for example, the number of typhoid germs present per unit volume at given points. Such tests can be made. But they are expensive of time and materials, and other tests, in which infection is measured indirectly, are sufficiently accurate. Hence the latter were employed in our investigation. Generally speaking, factors which condition infection and indicate pollution were measured rather than the infection and pollution themselves. Most of these factors have been spoken of in our fish-eye'd view of the river.

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[1] This is as true of "pure" as of "applied" science, the chief difference between the two being that in applied science the desired useful end is given at the outset of an investigation whereas the pure scientist has a less precise goal.

We've spoken, for instance, of dissolved oxygen content and of its importance to the good health of the stream. One of the routine laboratory tests measured the amount of dissolved oxygen present, comparing this with the amount (9.17 p.p.m. at 20 degrees C.) which water holds when saturated. More than 9.17 p.p.m. are occasionally found, incidentally: the stream may be "supersaturated" in the presence of an abundance of algae or other plant life.

Closely associated with this test was one for biochemical oxygen demand (B.O.D.), an ingenious indicator of organic pollution in that it measures the amount of oxygen required to oxidize the unstable organic compounds that are present. After the amount of dissolved oxygen has been measured, portions of the sample are sealed in test tubes and held for five days at 20 degrees C. At the end of that time the amount of oxygen is again measured, the difference representing the amount used by digesting organisms in their oxidation processes. In actual practice, the test is by no means as simple and easy as our description of it may imply: it is, indeed, very delicate and sensitive, requiring experienced skill for its accurate use:

but the basic procedure is as we've indicated, and the results are highly informative. To interpret them, it is necessary to remember that the capacity of a stream to "breathe in" oxygen varies inversely with temperature: the higher the temperature, the less oxygen, other things being equal. This fact, combined with the fact that the rate of biochemical oxidation increases with temperature, indicates that the most critical pollution conditions, so far as oxygen is concerned, are likely to occur in the summer months when, normally, temperatures are high in our Basin and stream flows are low. The oxygen demand is, of course, considered in relation to the amount of dissolved oxygen present. Whenever and wherever the demand is greater than the supply the river is dangerously ill.

These B.O.D. figures may be used to determine what are called "population equivalents," a convenient statistical language for expressing degrees of pollution. This becomes possible because the average composition of domestic sewage is fairly constant. In America, the average is 54 grams of B.O.D. per capita daily--which is to say that each person, on the average, commits to the toilet each day organic wastes requiring 54 grams of oxygen for digestion. (The amount tends to vary with the wealth of the person: the richer he is, the more putrescent matter he contributes--a fact which might tempt a contemporary Hugo into dangerous flights of metaphor, anti-Red hysteria being what it is.) The actual B.O.D. found in streams, however, is higher than it would be if domestic sewage were the only source of pollution. Analysis may reveal, for example, that sewage from a community of 1,000 persons contains 74 grams per capita daily of B.O.D., instead of the average 54. Simple arithmetic translates the larger figure into population equivalents. Thus: 1,000 x 74 ÷ 54 = 1,400 persons, in round figures. Or suppose a packing plant contributes to its sewers 10,000 gallons daily of sewage containing 800 p.p.m. of B.O.D.[1]. This has a population equivalent of 10,000 x 0.00379[2] x 800 ÷ 54 = 560 persons.

A third routine test of Kansas Basin samples was a measurement of turbidity, the suspended solid material which thickens and renders opaque the waters of the stream. Results were expressed in p.p.m. by weight--and as our fish-eye'd view would lead us to expect, a correlation was quite generally found between B.O.D. values, high and low stream stages, and p.p.m. of suspended solids. But of more immediate significance to sanitary engineers were the results of a fourth routine test, in which the "most probable number" (M.P.N.) of microorganisms of the coliform group was determined. Since these organisms occur in very small numbers in a natural stream, but are discharged in vast quantities in human feces, their presence in any considerable amount indicates domestic sewage pollution.

Routine tests were also made for alkalinity, measured in terms of quantity (p.p.m.) and intensity (pH values)[3]. The alkalinity of water generally indicates that carbonates, bicarbonates, and hydroxides are present. Associated with these tests were those for chlorides, whose entrance into streams creates a type of pollution particularly important and dangerous in our Basin. We shall return to it later on. Common table salt, as you know, is composed of one part sodium to one part chlorine, and the very name of the Saline River indicates a natural pollution with this substance. The natural pollution may be augmented by a careless disposal of oil field wastes, and our investigators were concerned to discover the extent of this latter damage.

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[1] B.O.D. can be expressed in p.p.m. by weight as easily as in grams, of course.
[2] One p.p.m. in a per capita volume of n gallons of sewage daily= 0.00379 n grams per capita daily.
[3] pH is the negative logarithm of the hydrogen ion concentration. Liquid whose pH value is 7.0 is "neutral"--i.e., neither acid nor alkaline. If it tests below 7.0 it is acid, and if above it is alkaline, the intensity increasing (up to a limit) with the difference between the test-value and the neutral point.

Such general characteristics of the streams as temperature, color, taste, odor and flow in cubic feet per second past sampling points[1], were also measured in the investigation. Special studies, as we've said, were made of some of the industries and sewage plants. When the results of all these studies were put together in comprehensive tables (listed in columns of figures, they added up to well over 100 full pages of small type), trained eyes could discern in them the nature and geographic pattern of pollution in this Basin. And when these were considered in conjunction with the distribution of population and industry, and with the sources of municipal water supplies, the specific needs of pollution control became evident.

A very general picture of all this is presented in figure 3. If you refer to it, you'll notice that 12 municipalities having a total population of 135,310 people draw their water from rivers in the Kansas system, while 291 municipalities draw water from ground supplies, through wells. A total of 145 cities have sewer systems serving 501,805 people and discharging into streams and rivers. The pollution resulting from the sewered population, however, is much greater than the domestic sewage of a half million people could produce. It is equivalent, in fact, to that which would be produced by 1,458,590 people, and the difference between actual population and the total population equivalent (B.O.D.) is accounted for by some 191 industrial establishments whose sewage discharge is equal to that of 946,545 people. Some reduction in pollution is brought about by sewage treatment, but the reduction is insufficient. It amounts to only 16.8 percent.

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[1] Arrangements were made with the District Office of the U. S. Geological Survey at Topeka, Kansas, and Lincoln, Nebraska, to cooperate in the development of these data.

The river's capacity for self-purification--that is, its ability to digest the wastes poured into it--was of course carefully studied, for it directly influences decisions as to the kind and amount of pollution control. In general, the main streams of our Basin were found to have somewhat higher digestive capacities than had been anticipated. The rate at which our streams use up dissolved oxygen in the digestion of organic pollutions is about what our scientists had expected. "Deoxygenation," this is called. But the ability of the stream to "soak up" oxygen ("reoxygenation") was somewhat greater than our scientists had expected. Probably this higher rate is due in part to the climatic characteristics of the region--to the fact that we have so much bright sunshine, which encourages algae and other plant organisms (particularly in warm and sluggish streams) to grow and multiply, releasing oxygen through photosynthesis. Certainly, what is called "surface reaeration," whereby air is physically lapped up by the surface of the stream, is not as high in our Basin as it is in mountainous regions where there are many rapids and waterfalls, and the streams run swift and cool. So algae must be given much of the credit for the fact that Kansas system streams contain, on the average, somewhat more than the 5 p.p.m. of dissolved oxygen which constitutes the minimum requirement for a balanced aquatic life.

But the self-purification ability of our streams varies greatly. It varies from place to place and from time to time. It varies with stream stage, for one thing. At higher stream flows, the dissolved oxygen content is actually less than might be expected, primarily because turbidity (mostly erosion silt) and organic pollution both go up as the water rises. Soil is washed from fields into streams in periods of high runoff, and farmyards and other areas of land surface bearing organic wastes are scoured.

Turbidity, as we've pointed out, means a decrease in light penetration, and this means a decrease in algae. Increased organic pollution, indicated by a higher B.O.D. and higher coliform numbers, means an increase in deoxygenation rates. Result: a more dangerous pollution of the stream. Here you may perceive a direct connection between the problems of pollution control and flood control. As peak stream flows are reduced by dams, and as streams are "ponded" in reservoirs, the total pollution load may be reduced and the growth of algae increased. On the other hand, "ponding" means a reduction in atmospheric aeration; sluggish or still waters do not lap up air as rapidly or in as great quantities as to free-flowing streams.

There becomes evident, once again, the need for integrated river development. Otherwise, from the standpoint of pollution control, the control of floods through dams and reservoirs may be no unmixed blessing in our Basin, and irrigation developments may be a positive evil.

In the first place, algae growths, valuable within limits, may be encouraged beyond those limits in impounded waters. Released downstream, such excessive growths may mean an increase in unpleasant tastes and odors which must be removed by water treatment in those municipalities drawing their drinking water from streams. Such tastes and odors, difficult and expensive to remove in even the most efficient plants, have long presented one of the most vexing problems faced by waterworks engineers in our Basin. Any increase in them will be decidedly unwelcomed.

In the second place, the Tuttle Creek Reservoir on the Big Blue (see figure 1, page ___) a project which has received Congressional approval, may create special water supply and pollution control problems at Marysville, Kansas. This town of 4,000 draws its water supply from the Blue, and discharges raw sewage into the Blue. If the final design of the Tuttle Creek Reservoir is such that the Blue is "surcharged" to Marysville, the town's raw sewage will be backed up into the water supply. As we shall emphasize later, Marysville should not be discharging raw sewage into the river, nor should any other towns; a sewage treatment plant should and will be built. But even so, new arrangements for both drinking water and sewage disposal--probably a relocation of water intake and sewage discharge pipes--will be needed if the "high pool stage" indicated on a Corps of Engineers map, issued in March of 1947, is actually developed for Tuttle Creek.

In the third place, and still more serious in terms of pollution control, are the consequences of any drastic reduction of flows in the main stem of the Kaw, as a result of irrigation diversions from the Republican River below the Harlan County Dam (see figure 1, page___). Just in general, and other things being equal, a stream's ability to digest wastes varies directly with the size of its normal flows. For this reason alone, and great reduction of minimum flows, and average flows, means that municipalities will have to spend more money on sewage treatment in order to maintain, or restore, the health of the river. But the problem for the Kaw's main stem is further complicated by the fact that water from the Republican dilutes the waters from the Smoky Hill system where the main stem forms at Junction City, and the latter waters have what sanitary engineers call "poor mineral quality." As we've pointed out, the very name of the Saline River indicates a natural pollution with sodium chloride and other salts, and this pollution can be augmented by oil field waste disposals. Our point now is that any important reduction in the Republican's flow will have adverse effects on the quality of the river below Junction City. The stream's capacity for self-purification will be reduced, and the costs of sewage treatment and water purification will go up.

All these problems are soluble, of course. But the difficulty and cost of their solution can be much reduced if they are properly anticipated in overall Basin plans....

Let us now begin at the lower reaches of the Kansas system and move upstream, taking note of the salient features of the pollution problem as we proceed.

The sub-basin drained directly by the Kaw itself (see figure 1, page ____) extends westward from Kansas City to Junction City, and is by far the most heavily populated of all the sub-basins of the Kansas system. It contains 38 municipalities of which four are, for this region, considerable towns: Kansas City, Kansas, with 147,000 people[1]; Topeka with 87,000; Lawrence, with 18,000; and Manhattan, with 13,500. Of these four, two--Topeka and Lawrence--draw drinking water directly from the Kaw. Three other towns--Olathe, with 5,000 people; Horton, with 3,000; and Onaga, with 900--draw their water from tributaries. The other municipalities draw their water from ground sources.

Not only is this the most heavily populated of all the sub-basins, it is also the most industrialized. The sewered population (the number of actual living people who commit their organic wastes to sewers) is approximately 260,000, but the amount of stream pollution produced (B.O.D.) is equivalent to a population of about 1,060,000. Subtract the first figure from the last and you find that a pollution population-equivalent of 800,000 is contributed by industries. The pollution produced by the combination of domestic and industrial sewage is reduced by sewage treatment plants to a sewered population equivalent of about 940,000 before being discharged into the stream. This reduction is not enough to maintain stream quality and insure public health. Even if Kansas City, at the Kaw's mouth, be excluded from consideration, sewage treatment remains inadequate. The sewered population equivalent connected to sewage treatment plants amounts to 69 percent of the total.

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[1] Based on estimates in Kansas State Board of Agriculture Bulletin "Population of Kansas", August 24, 1948.

By far the most important contributors of organic wastes to the subbasin streams are the food processing industries: meat packing plants, poultry dressing stations, canneries, and creameries. These are concentrated on the banks of streams in order that they may use the flowing waters for the disposal of wastes. Kansas City's world-famous packing industry, for example, stands on the natural flood plain of the Kaw and Missouri, and its contribution of organic wastes is far greater, just by itself, than that of the city's total population. The total population connected to sewers there is 103,000[1], but the sewered population equivalent (all of it untreated in sewage plants) is 777,000! Domestic sewage, in other words, amounts to considerably less than one-seventh of the total pollution which Kansas City consigns to the already over-burdened Kaw. Here, of all places in the Basin, the river is most foul. In our survey, those who sampled the river here noted "floating garbage, oil, and coarse sewage solids, all indicative of gross pollution"--and these visual evidences were more than confirmed by later laboratory tests for dissolved oxygen, coliforms, B.O.D., and so on.

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[1] This in itself is a distressingly significant figure, taken in conjunction with the fact that Kansas City's total population is around 147,000. It indicates that some 44,000 people in this modern city lack indoor plumbing facilities. This is nearly 30 percent of the total population! There is a far more serious substandard housing problem than comfortably-placed people like to admit, and it frankly worries the Kansas State Board of Health.

Topeka, too, some 82 river-miles upstream, has a considerable packing plant and creamery industry. As early as 1885 the Kansas Board of Health was concerned about the State capital's river pollution. A report of the Board referred to the famous cry of a sacred singer of Israel, as recorded in the Bible: "Moab is my washpot:" and suggested that Topeka could parallel this with, "The Kaw is my washpot and my ice-pond"--for in those days ice was cut from the river in winter. Polluted ice is no longer a major health problem, but in other respects the Kaw's pollution at Topeka has not, alas, improved. More than two-thirds of the city's sewage goes raw into the river. Twenty miles downstream, Lawrence takes its water from that river, purifies it, drinks it, and flushes most of it back into the stream bearing domestic sewage and industrial wastes. Twenty miles below Lawrence's sewage discharge lies the intake of the largest water treatment plant in Kansas, that of the Sunflower Ordnance Works which, though now shut down, is ready for swift reactivation in case of war emergency. And twenty miles below the Sunflower intake lies Kansas City.... You can see how pollution is compounded as populations and industrial concentrations increase.

Of the towns on small tributaries of the Kaw, Tonganoxie has contributed perhaps the most serious pollution problem. It was so serious, in fact, that the Kansas Board of Health was forced to take action in the interests of public health. Only 1,000 people live here, and they maintain a treatment plant for domestic sewage. Nevertheless, a pollution population equivalent of 3,580 goes untreated into Tonganoxie Creek, 3.1 miles above that stream's entrance into the Kaw. The major source of this pollution is a milk processing plant, whose wastes have gone untreated. (A treatment plant for these wastes has been planned, and construction may be under way by the time this little book is published.)

The sub-basin drained by the Big Blue River has an over-all pollution problem much less serious than that along the main stem, but having the same general pattern. The population connected to sewers totals 87,000, while industrial wastes (mostly from food processing plants) amount to a population equivalent of 40,200 people, before treatment. There is some treatment, however. It cuts the total pollution from 127,000 to a little less than 74,000, in population equivalent terms. Fourteen of the 47 sewered municipalities in this sub-basin, having a sewered population equivalent of approximately 53,000, discharge raw sewage into the streams. Only three municipalities, however, draw their water from surface sources. Of these only Marysville, Kansas, draws from the Blue itself.

The most serious local pollution problem in this sub-basin is perhaps that of Hastings, Nebraska, a city of 16,000[1] on the far reaches of the West Fork tributary of the Blue. This stream is so small that the discharged sewage below Hastings constitutes, in dry summer months, a substantial portion of the total flow. The result has been a serious public nuisance at various times, and no small threat to public health. More sewage treatment is necessary, and Hastings plans to build new and expanded treatment facilities. Similar overloadings of small streams were encountered at Aurora, on Lincoln Creek in Nebraska, and at York, on Beaver Creek. At only 12 points in this sub-basin did our investigators find the B.O.D. to be in excess of 5 p.p.m. Four of these points were below Hastings, three were below Aurora, and two were below York.

Thus we encounter a factor which is of relatively small importance to the pollution problem in the main Kaw sub-basin but of increasing importance as we move westward into the land of little rain. It is the factor of low and intermittent stream flows. Obviously very small populations can dangerously pollute a stream which, in dry periods, tends to disintegrate into a succession of stagnant pools, or to disappear altogether.

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[1] Figure based on 1940 Census.

Such streams are common in the Republican River Sub-Basin, particularly in the western portions. The bulk of the Kansas Basin Reservoir developments lie in this sub-basin. Of the 34 reservoirs planned for the Basin as a whole, 22, or two-thirds of the total, lie on the Republican and its tributaries. Of the six reservoirs now under construction, all but two lie in the Republican drainage area. These reservoirs constitute a major factor in the sub-basin's pollution control problem.

This is thinly populated country. In an area of approximately 25,000 square miles live fewer than 80,000 people, and of the 103 towns and villages only four have populations in excess of 5,000. The largest town in the entire area is Junction City, at the mouth of the Republican, with 11,000 people. As for industrial wastes going into the streams, they have a sewered population equivalent of less than 41,000, and this added to domestic sewage gives a total pollution load equivalent of only slightly more than 120,000. This is reduced 25 percent--to 90,400--by treatment. Surely our investigators were justified in characterizing the sources of pollution here as "only moderate."

But they were equally justified in their insistance that, however small quantitatively the amount of raw sewage and wastes dumped into the streams, the wastes create serious pollution problems. Why? Because the streams have so little water in them, and because the amounts fluctuate so widely. They fluctuate, too, in peculiar ways. Normally a river increases in volume as it flows downstream. How could it do otherwise? It is being constantly fed by its tributaries and by runoff water along its banks. Yet the Republican and its branches do not, over major portions of their courses and during critical periods, follow this seemingly inevitable pattern. Instead they often carry less water downstream than they did upstream. The minimum monthly mean flow at Max, Nebraska, for example, is 1 cubic foot per second, while 35 miles downstream, at Culbertson, Nebraska, the minimum flow is zero. In the North Fork Republican River the minimum monthly mean flow is 14 c.f.s.; in Frenchman Creek, it is 63 c.f.s.; in Medicine Creek, 20 c.f.s. Yet the minimum flow in the main stem below these tributaries may be zero.

The U. S. Geological Survey, in its Water-Supply Paper 273, describes matters thus: "Throughout its course in Nebraska (the Republican) flows in cretaceous deposits and is supplied by spring-fed tributaries. In the western counties, where the rainfall is small and the direct run-off rapid, the river is often dry, as for example, in midsummer, immediately above mouths of Buffalo, Rock, and Frenchman Creeks, but these streams revive the flow of the river below their mouths. Such alternating dryness and flow extend as far east as Superior, Nebraska, during droughts, but only once in 12 years has the river ceased to flow at Red Cloud and Superior."

What causes the river to deplete so drastically when, by ordinary standards, it ought to prosper? Evaporation is undoubtedly a major factor. The Republican is, by and large, a wide and shallow river. A large percentage of its total volume lies exposed to the dry hot winds and blazing suns of summer. Evaporation rates approach 10 inches a month during July, in the vicinity of the Harlan County dam, and such thieving raids upon a river already shrunken, might by themselves, reduce its flow to nothing. Add to this the water lost to narrow jungles of cottonwood and willow along the banks, and the water used in irrigation--for in the western reaches, the whole stream is sometimes diverted for irrigation--add these losses, and the river's disappearance along stretches between the mouths of spring-fed tributaries becomes plausible.

But our point is that such streams make mighty poor fluid wastebaskets. Stinking Water Creek, one of them is called--and more than one deserve the name below outlets for untreated, or inadequately treated, sewage.

Take McCook in western Nebraska, for example. Here the Republican's flow is erratic indeed. Its "normal" flows varied from 150 to 350 cubic feet per second during the months of our investigation (June through December), but they ran as high as 2200 after heavy rains and as low as 15 during dry spells. To dump any considerable amounts of raw sewage into a stream with these characteristics is to court trouble. Yet that is what McCook has been doing. Its septic tank treatment plant was found by our investigators to be wholly ineffectual. As a result the town, with a sewered population of 7,500 and a considerable industry, has been dumping into the river a pollution load equivalent to that produced by 14,300 people.

A similar though somewhat less serious pollution problem occurs below Superior, Nebraska, during low stream stages. And even downstream, where the river is larger, serious local pollutions are brought about by raw sewage disposals--for here the towns, generally speaking, are larger, too, and farmyards are closer together. Orleans, Alma, and Red Cloud in

Nebraska; Concordia, Clay Center, and Junction City in Kansas--all pollute the stream with wholly untreated sewage.

The Orleans and Alma situations are given a special significance by the Harlan County Dam. The lake which will form behind that dam, with its miles of shoreline, will be developed for recreational uses: swimming, boating, fishing, picnicking. Yet Orleans, only three miles or so above the upper end of that lake, discharges its sewage raw into the Republican--and that sewage includes the wastes of what is reputed to be the largest co-operative creamery in the world. Though only 815 people are "connected" with sewers in Orleans, the pollution load has a population equivalent of 3500--enough to make swimming a hazardous enterprise in the upper reaches of the lake. Concerning Alma, the situation is even more serious. The town lies directly on the shoreline, has a sewered population of 1,700, and a considerable packing industry. Its pollution load, now dumped raw into the river is equivalent to that of a population of 4,370.

Already mentioned have been the possible consequences of the Harlan County project on the mineral quality of the Kaw itself. Four pumping stations, two diversions, and extensive canal system comprise the proposed irrigation developments below the big dam, and the river-bordering belt of irrigable lands, containing approximately______ acres, extends all the way from Alma, Nebraska, to a few miles north of Concordia--a distance of 134 river-miles. It is precisely here, at Concordia, that high salt concentrations are first introduced to the Republican. Buffalo Creek, which enters the Republican near Concordia, draws from salt springs and marshes in Jewell County, Kansas, and from the salty Jamestown Marsh and the Little Marsh near Jamestown and Yuma, Kansas. Salt Creek, which discharges into the Republican several miles below Concordia, drains a salt marsh to the north. These discharges are, of course, reflected in the laboratory data on chloride concentrations. They do not, under present conditions of stream flow, constitute a particularly serious pollution problem, but if the upstream irrigation project drastically reduces flows below Concordia, even the Republican's waters may have a much lowered mineral quality. And when these waters mingle with those of the Smoky Hill at Junction City to form the Kaw, a truly serious downstream mineral pollution may be developed.

For saltiness is the pollution quality which chiefly distinguishes the Smoky Hill Sub-Basin from the other sub-basins of the Kansas. The Smoky Hill system has three main divisions: the drainage area of the Solomon, which branches off the main stream a few miles west of Abilene; the Saline, which branches off at Salina; and the Smoky Hill itself, which drains the southwestern portion of the entire Basin. Each of these divides into numerous fingers probing the High Plains of western Kansas and eastern Colorado. As regards low and intermittent stream flows, and the pollution problems arising therefrom, this sub-basin is not markedly different from the Republican. But as regards salinity it is, in our Basin, unique.

The problem, as might be expected, is concentrated in the drainage area of the Saline. Most of the 3425 square miles of this area is underlain by a salt formation; were it completely excavated and spread evenly over the surface of Kansas, the entire State would be blanketed by a layer of solid sodium chloride 37 feet thick; and natural salt springs occur in the bed of the Saline and all its tributaries. To this natural pollution was added, in the 1920's and thereafter, the salt brine disposals from oil and gas wells--for extensive fields of these lie within the Saline watershed. As much as 400 barrels of salt brine may be pumped to obtain one barrel of oil in the Kansas fields, and one barrel of high chloride oil brine may so contaminate 200 barrels of fresh water that it cannot be used for domestic purposes.

Popular pressure quickly dissuaded most oil companies from piping brine directly into streams, but their first alternative to this was but little better. It consisted of building ponds for holding the brine on the surface of the ground. Seeping down through soil and rock formations, the salt solutions polluted ground waters, which meant poisoned wells. It meant also, and eventually, poisoned streams--for streams are continuously fed by ground waters through springs. There is, indeed, no sharp distinction in nature between ground and surface waters; the two are continuous, minimum or basic stream flows being maintained during drouth periods by ground waters.

Now of all forms of pollution, this is the most deadly in the literal meaning of the word. No fish, nor any other kind of aquatic life, can exist in a high chloride stream, and this means that the stream's capacity for self-purification through oxidation processes is completely eliminated. Organic wastes dumped into it must remain undigested. The damage, moreover, is permanent. Salt dissolved in a river remains in solution all the way downstream and the only way in which such pollution can be overcome is by dilution with fresh waters. Thus the Kansas State Board of Health found itself face to face with a pollution problem of emergency proportions, and it is to the credit of the Board's Sanitation Division and of the people of the State that the reaction to this emergency has been both prompt and effective.

First, geologists and engineers worked out a method by which brine may be safely disposed of. Briefly, it consists of drilling deep wells, reaching depths well below the oil-bearing formation, and then pumping the brine into these. Second, a series of statutes pertaining to oil field waters was enacted by the Kansas legislature--for candour compels the admission that, in such cases as this, civic conscience cannot be depended upon to secure, unaided, the needed compliance: drilling deep wells costs money. Third, the legislation was tested in a series of suits brought by the oil companies or by the Board of Health and won, in every case, by the latter. In consequence, Kansas is now far ahead of other States in its solution to this particular problem. Russell County alone has more disposal wells than all the rest of the United States. Moreover civic virtue--even a coerced civic virtue--has proved to be individually profitable. Wherever this disposal method is used, oil production has been unexpectedly yet significantly increased.

But as we've pointed out, natural salt pollution remains a problem whose possible enhancement, by a reduction in Republican stream flows, is cause for grave concern. It determined a special attention to chloride concentrations by our Basin investigators. The data they secured on the Saline clearly indicated the effectiveness of the Board of Health program; oil and gas fields are not now increasing, to any appreciable extent, the salt content of this river. Nevertheless the average chloride concentration was 932 p.p.m. 167 miles above the river mouth, reached a peak of 1245 p.p.m. ten miles downstream, and varied from 608 to 881 thereafter nearly all the way to the mouth. Maximum concentrations varied from 1,000 to 2,000 over this distance. The significance of these figures is pointed up by the fact that Federal drinking water standards permit a maximum chloride concentration of only 250 p.p.m. while fish life is drastically reduced when concentrations are greater than_________.

Generally speaking, organic pollution problems within the Smoky Hill system are local in nature and relatively minor in importance. For the most part, sources of pollution are far enough apart to permit the stream to "recover" between them. Within the 30,222 square miles drained by the Smoky Hill and its branches lives a sewered population of 77,035. Industrial wastes are equivalent (B.O.D.) to an additional population of 26,685. The total pollution load is equal to that of 103,720 people, but this is reduced to 63,684 through sewage treatment. The principal treatment deficiencies lie within the Solomon drainage area where the Kansas towns of Beloit, Glasco, and Minneapolis all dump their sewage raw into the river and where Downs and Osborne provide a wholly inadequate treatment.

A quite serious pollution has occurred below Salina, Kansas, but this will presumably be prevented by a sewage plant now under construction.

3.

The Sickness of the River and the Health of Man

It is necessary to keep the river's disease, which is highly infectuous, from spreading to man. The waters we have fouled must be cleansed before we partake of them. For this we spend millions.

Approximately 35,000,000 people in the United States, and more than half our industries, depend upon filtered surface water supplies--water drawn from streams and reservoirs. About 1,500,000,000,000 (that's 1,500 billion!) gallons are treated and filtered annually in this country at a cost estimated several years ago at $150,000,000 and the cost goes up as pollution increases.

In the Kansas Basin, ______ municipalities draw all of substantial portions of their water from rivers. These communities spend $________ annually to maintain and operate water treatment plants. Even so, they do not spend enough. In 1946, the Kansas State Board of Health, in cooperation with the U. S. Public Health Service, made a study of public water supply facilities in Kansas as a whole and found that $21,200,000[1] worth of improvements were needed to safeguard public health. A considerable portion of this total was assigned to communities drawing on rivers in the Kaw system. There has been some improvement since 1946, but as this is written, 25 percent of all the public water supplies in Kansas still do not meet the Drinking Water Standards of the Public Health Service. Periodic outbreaks of intestinal disturbances still occur. An outbreak of infant diarrhea at Emporia (outside the Kaw Basin) killed at least eight children and dangerously sickened 20 others, in November of 1948. And since such infections are both sudden and widespread, a source common to many people is indicated. Almost invariably the public water supply is accused. Though guilt remains generally unproved (the exact cause of such outbreaks has been seldom discovered), the charge is plausible, to say the least.

We've indicated, in our preceding section, how a substantial part of water treatment expense must go toward removing the pollution caused by excessive raw sewage disposals upstream. Marysville, Kansas, for example, finds its water problems complicated and its treatment costs increased by raw sewage dumped into the Big Blue by Beatrice, Nebraska, a city of 13,000 some 50 miles upstream. We've mentioned Lawrence, Kansas. It spends considerably more on water treatment each year than it would have to spend were not the Kaw dangerously polluted 35 miles upstream by Topeka, a city of more than 80,000 with extensive manufacturers and large packing plants. Topeka does have a sewage treatment plant, but it is inadequate. Only about a third of the city's sewage is treated there when the plant is running, and when it is shut down--as it often is during times of high water, in order to clean the tanks (and this at the precise time when pollution is most serious!)--all Topeka's sewage goes raw into the river.

The process of treatment at Lawrence is typical. This city of 18,000 draws two-thirds of its water from the Kaw, the other third from wells, treating it in a plant built in 1916. First the water is partially sterilized with chlorine; pre-chlorination this is called, because it takes place prior to the main treatment. Then the water is treated with alum, iron, and lime for flocculation, alum (as aluminum sulphate) reacting with lime to form aluminum hydroxide, iron sulphate reacting with lime to form iron hydroxide. The flocculent thus produced sweeps like an extremely fine-toothed comb through the water, cleaning out suspended materials. The water then pours (looking like smoke, with flocculent) into settling basins, where solids settle out, after which it flows through a succession of filters. These are layers of sand of a specified size, 36 inches thick and topped (in the Lawrence works) by finely ground coal. The water is then "softened" by treatment with lime and soda ash--which takes out such substances as iron manganese--after which bicarbonate (having an acid reaction) is used to reduce the softener-induced alkalinity. The water is finally chlorinated again (post-chlorination) and pumped into the pipes of the Lawrence water system. Every other day, each filter is cleaned by a process called "back-washing". The filter tank is emptied, water is forced through the sand from the bottom, and the accumulated filth of 48 hours boils up in liquid clouds to be flushed away by powerful streams of clean water.

In this way, the Lawrence plant treats some 3,000,000 gallons of water daily, or about 2,000 gallons per minute. The annual cost of operation, including plant repairs and replacements, wages for employees, and treating materials, amounts to __________ per capita, and to this must be added amortization costs of the original plant investment. In smaller communities, the per capita costs of safe water go up. Building a waterworks may cost only 1 to 8 percent of the annual spendable incomes of citizens in the larger towns of the Basin as compared to 25 or 35 percent for those living in towns of a few hundred. It is in consequence of this that health problems arising from unsanitary water are most serious in these little towns....

Nor is the use of water for domestic purposes the only way in which the river's disease may be communicated to man. Swimmers almost invariably swallow some of the water in which they swim, and many a case of typhoid has been attributed to swimming in polluted streams. Hence the concern over the Orleans and Alma, Nebraska, sewage disposal in waters which, as part of the Harlan County reservoir development, will be used for recreation. Still more serious is the public health threat posed by use of polluted waters for irrigation. A death-breeding short-cut from anus to mouth is all-too-efficiently achieved if low-growing fruits and vegetables are irrigated with raw sewage and then consumed by men. Even field crops such as corn may become contaminated if irrigated with diseased waters. In general, water diverted from the river channel for irrigation purposes is removed from areas of limited access and spread over areas where many men, and their livestock, may make contact with it. It is therefore especially important that a river so used be healthy.

Part Five

TO CLEANSE OUR STREAMS

1. The Pollution Pattern is a Pattern for Action

2. There Ought to be a Law!

3. Silt Pollution: A Wider Reference

TO CLEANSE OUR STREAMS

1.

The Pollution Pattern is a Pattern for Action

We have said that when a scientist investigates an object he traces out a pattern of possible action upon it. Essentially the process of investigation *is* a programming of action. Certainly that is true in the present case. As our investigators made a precise definition of the pollution problem in the Kansas Basin they developed a detailed outline of the problem's solution, and insofar as the definition was confined to technical matters the solution is similarly limited. (The fact that the river is a social as well as a technical problem complicates matters, as we've seen.) Technically speaking, then, we know what to do--and what *not* to do--to solve the Kansas Basin problem.

So far as sewage pollution is concerned, we may sum up both the positive and the negative in a maxim: *no sewage whatever should be dumped raw into a stream; ALL should be treated before being disposed of in rivers.* The degree of needed treatment varies, however, with the amount and kind of sewage and the quantity and quality of water in the river. Sometimes "primary" treatment is sufficient, taken in conjunction with the stream's natural digestive capacities. Sometimes "secondary" treatment is also necessary. And if you'll refer to figure 3, page _____, you'll see listed the treatment requirements and recommendations for municipalities in our Basin having sewered population equivalents of 1,000 or more. You'll note that of the 90 municipalities listed, only 41 now have adequate sewage treatment. Thirty towns have no treatment plants whatever, and should build them. Six other towns have obsolete plants, which should be replaced. And all the remainder, because of inadequate plant or faulty operation of equipment, or both, continue to poison our streams with their wastes. In 29 of the communities where treatment is badly needed, no program for obtaining it was contemplated when our investigation was made.

Statistics on needed treatment are not very meaningful, however, unless we have some general conception of the treatment processes themselves. What constitutes "primary" treatment? What, "secondary?"

The former is as simple as can be. Merely running the sewage water through a fine screen will reduce the amount of suspended solids by 20 to 25 percent, the number of bacteria by 10 to 20 percent, and the amount of oxygen required for digestion by 5 or 10 percent. If to screening is added a sedimentation process, whereby the sewage water is held in settling basins for a specified length of time, from 40 to 70 percent of the suspended solids is removed, the bacterial count is reduced anywhere from 25 to 75 percent, and the oxygen demand is cut by 25 to 40 percent. These two processes of screening and sedimentation constitute "primary" treatment, and, we repeat, no sewage whatever should be dumped in the river without having had at least this much reduction.

Of "secondary" treatments--and some such treatment is absolutely needed where the proportion of sewage to river volume is high--there are two main kinds.

The more complex of the two is the "activated sludge" process whereby partially digested sewage solids, properly "activated" with bacteria are used to speed the digestion of new, raw sewage. The one-third (or less) of Topeka's sewage which is treated at all goes through an activated sludge plant. Here the basic operations are three: First, the sewage, after passing through screens and settling tanks, is mixed with from 20 to 35 percent of its volume of biologically active sludge. Second, the mixture is agitated with air, which is forced through it and in the presence of which the bacterial digesters multiply rapidly; organic solids are swiftly oxidised and suspended materials tend to coagulate in forms which are easily settleable. Third, this final settlement takes place in special tanks. The water which flows out at the end of this process--the "effluent" as it is called--is clear and sparkling, and contains very little organic material. It is safer to drink, as a matter of fact, than some of the water people do drink in the small towns and rural areas of the Basin.

The other main secondary treatment is the "trickling filter" process, so-named because its principal element is the trickling of sewage water over and through a 6 to 8-foot deep bed of broken stones, each of which is 2 to 3 inches thick. A great advantage of this process, and one which recommends it highly to small communities, is its simplicity. No considerable technical knowledge is required for its comprehension, and its operation requires little skill. The process, indeed, is virtually automatic.

Take the Smith Center, Kansas, plant, for example--built in the late 1940's after decades in which the town's filth piled up in a stinking, fly-breeding mess below the sewage outlet. The sewage water now enters the plant through a screen, which separates out the coarser solids, flowing thence into a settling basin, called an Imhoff tank after the German (Karl Imhoff) who invented it. This tank is designed in such a way that gas bubbles from digesting solids, at its bottom will not agitate the raw sewage above sufficiently to interfere with further settling. The tank stands several feet above the circular filtering bed. This enables a siphon arrangement at the exit trough to operate a rotary distributor, turning above the bed. Through it, the sewage water (which has now had primary treatment) is sprayed over the coarse stones. From the filter bottom, through an underdrain system, the sewage water goes into the final settling tank from which the sludge--a black tarlike substance--is obtained. This sludge may then be thrown back into the Imhoff tank for digestion, or it may be put into a special digestion tank. Again, the effluent is clear, sparkling water containing very small amounts of organic material.

Activated sludge plants, properly operated, will reduce the oxygen demand by 85 to 95 percent, the suspended solids in the same proportion, and will remove from 90 to 98 percent of all bacteria. Trickling filter plants are only slightly less effective. They'll reduce oxygen demand by 80 to 95 percent, suspended solids by 70 to 92 percent, and bacteria by 90 to 95 percent.

But the prevention of pollution is not the sole value which may be obtained from these treatmeht processes. The fermentation of sludge in a digestion tank yields a highly combustible gas which may be piped away and used to operate plant machinery. The gas produced at the Topeka plant is so used, and in some cities considerable areas are lighted with electricity produced by generators whose only fuel is sewer gas. Important portions of plant operating cost may be so recovered. And further recoveries may be made if, with our science, we follow the good advice of Victor Hugo in LES MISERABLES and return to the soil some of the wealth we have taken from it. Doing so enables us to reverse a pernicious process. By reversal we can, indeed, change the process to a beneficence, for instead of spreading disease we improve health. Thus:

The sewage sludge which is left after complete digestion comprises a humus immensely rich in plant food, and sludge is even richer in nitrates if digestion is not carried to its ultimate end--as it need not be. There exists in all the world no better substance for revivifying an exhausted soil, and it is a clean substance which, unlike barnyard manure, may be pleasantly as well as safely handled. Phosphorus and potassium, in addition to nitrogen, are found here in proportions that compare favorably with most manufactured fertilizers, and in forms more readily assimilable by living plants. Also found are elements which, though needed by the plant in very small quantities, are nonetheless essential to its healthy growth--such elements as sulfur, iron, manganese, magnesium, boron, copper, and zinc. These are generally not found at all in the fertilizer one buys.

At present, in recklessly extravagant America, most of this wealth is thrown away. At Smith Center, Kansas, for example, great piles of it stand below the final settling basin, seemingly undiscovered by enterprising farmers or gardeners. But there are a few cities which pay substantial portions of their sewage treatment costs by marketing the treatment's end-product. "Milorganite" is the trade name for the fertilizer (unfortified sewage sludge) produced by Milwaukee, and "Soiltone" is the trade name for the dry, pulverized, digested sludge obtained from the Lincoln, the Omaha, and the Des Moines plants. It is to be hoped that the example provided by these cities will be increasingly imitated....

Thus we possess techniques for preventing, absolutely, the pollution of streams through sewage disposals in them. We have only to respect with our science the living integrity of the river, never assigning to its waters a greater organic waste than those waters can safely consume. We possess, too, in the red-backed report of our Basin investigation, specific recommendations for the application of these techniques to the Kansas System. There remains the necessity for carrying out these recommendations, a process requiring social action.

In Kansas, the action was promptly initiated, as those who know the State well would expect it to be.

If Kansas has not always been notably progressive in other fields of social legislation, she has always been so in the field of public health. A social philosopher might explain it by referring to the Puritan tradition in which the State was founded and to which she yet, in several respects, adheres. Cleanliness is next to Godliness, the old saying goes, and Kansans seem to believe that the purity of one's spirit can shine only through a body well-scrubbed and healthy. Whatever the reason, Kansas organized her State Board of Health in 1885, has consistently given it a greater authority and a firmer financial support than most such boards receive, and through it has pioneered many a valuable health movement. The famed "Swat the Fly" campaign which swept the nation in the early 1900's was initiated by the then State Health Officer of Kansas, Dr. _. _. Crumbine. In 1907, a model stream pollution control act was passed by the Kansas legislature, requiring each city or industry to obtain a permit from the Health Board before running wastes into a stream. In 1909, Kansas outlawed the common drinking cup--the first State to do so. It was a Kansas school teacher, Frank Rose, who invented the fly swatter in 1906, and a few years later another Kansan, Hugh Moore, invented the sanitary paper drinking cup and the penny-cup vending machine.

Thus the Kansas Board's Sanitation Division (established in 1907, when the basic water pollution act was passed) followed distinguished precedent when it worked out a proposed policy for pollution abatement, a few months after the Basin investigation was completed. Public hearings on the proposed policy were held in all major communities affected by it, and in consequence of the overwhelmingly favorable response to it, the policy was adopted. As outlined in April, 1950, the policy's stated goals were:

"1. That at minimum stream flows the biochemical oxygen demand exerted on any one section of a stream shall not reduce the dissolved oxygen content below 5 parts per million.

"2. That at minimum stream flows the goal for coliform bacteria is 20,000 organisms or less per millileter....

"3. That the primary treatment of sewage is the minimum amount which will be accepted.

"4. Where oil pollution is concerned, all above-ground oil storage tanks shall be surrounded by an earth dike with a capacity equal to the contents of the tank plus a free board of 1.5 feet.

"5. All brine ponds and waste oil ponds shall be operated in such a manner that 2.5 feet is provided above the maximum brine level.

"6. That no brines from any field in the river basin shall continue to be stored in ponds, or discharged directly

> or through seepage to a fresh water course, either surface or subsurface, after July 1, 1951, which date has previously been set by the Kansas State Board of Health...."

Cities and industries providing no sewage treatment at all (and this includes those having treatment plants built prior to 1920) are required, by the policy, to have engineering reports and plans prepared by January 1, 1952, if they have more than 3,000 population, and by January 1, 1953, if they have less. Contracts for construction must be let within a year following these dates. Cities and industries which have inadequate treatment are required to submit an engineering report to the Board showing proposed improvements by January 1, 1952, and all work must be contracted for by January 1, 1955, at the latest. "Pollution hazards in some areas will require that this schedule be advanced."

In many Kansas cities, including Kansas City, Kansas, pollution hazards are vastly increased by a system of so-called "combined sewers" whereby storm runoff and sewage are run together. The Health Board policy calls for the elimination of these in accordance with the time limit for sewage treatment outlined above--save in the case of Kansas City which "presents an involved and complicated problem." Here an extended time limit is provided, not only for separating storm from sanitary sewers but also for building a treatment plant, or plants. Plans for the former enterprise are to be completed by January 1, 1953, and they are to include a schedule for completing the project within 10 years thereafter. Plans for a sewage treatment plant, or plants, are to be completed by January 1, 1960, and a contract let by that time for construction of the plant.

"In enforcing this policy," announces the Board of Health, "no sewerage permits will be granted to cities not maintaining a program in accordance with the above schedule."

The permit system in Kansas does constitute effective enforcement. The basic 1907 law provided that the discharge of sewage without a permit may be punished by an initial fine of $500 and a further penalty of $50 for each day of such discharge. Failure to comply with a Board of Health order to a "person, company, institution or municipality" may be punished by fines ranging from $25 to $100 for each offense, and each day of failure constitutes a separate offense. Failure to comply with Board regulations may be punished by fines of from $100 to $250 a day. Such a system can be maintained, of course, only by a firm popular support.

Kansas laws also make ample provision for cooperation with the Federal government in its general health program and in the specific activities authorised under the Federal Water Pollution Control Act. An instance of this is, of course, the prompt response of Kansas to the Basin survey recommendations.

2.

There Ought to be a Law!

The other two States involved in the investigation have not, as this is written, responded to the recommendations as effectively as Kansas has done. In large part this is due to deficiencies in enabling legislation, both in Nebraska and Colorado, and to inadequate provisions for staff.

In Nebraska, there is no comprehensive water pollution control legislation of the kind Kansas has had since 1907. The only statutory authority for water pollution control is provided in a section of the State's Revised Statutes which says that "the Department of Health shall have general supervision and control over matters relating to public health and sanitation...."

An Attorney General's ruling designates the State Department of Health as the water pollution control agency, but the Department has nothing approaching Kansas's Sanitation Division in scope or effectiveness. The Sanitation Division it does maintain is inadequately staffed and its functions are almost exclusively advisory and educational. No sewage discharge permit system is now in operation, nor is specific authority for the issuance of pollution abatement orders provided by legislation. Moreover there is, at present, some division of authority between the Health Department and the State Fish and Game Authority, the latter having authority to act through county attorneys to obtain abatement of pollution harmful to aquatic life.

Despite these serious handicaps, Nebraska's Department of Health has a fairly good record of pollution control, according to our Basin investigators--a high tribute to the quality of the Department's personnel. The legislative handicaps should, however, be removed as quickly as possible. The Basin report strongly recommends that Nebraska enact the needed comprehensive legislation, designating a single State agency to have authority over all aspects of water pollution. Presumably this agency would be the State Health Department whose powers would be no longer limited to the public health aspects of water pollution but would have to do with all pollution detrimental to water use. It would be enabled to establish a sewage discharge permit system, to set up rules and regulations concerning pollution, and to issue orders for pollution abatement. This legislation should, of course, be implemented with adequate appropriations for staff increases where these are needed.

In some respects, Colorado's pollution control legislation is even less adequate and more confused than Nebraska's. Here again we find no comprehensive pollution control legislation. The State Department of Health is designated as the State's pollution control agency but its activities are limited to the public health aspects of the problem. It shares a confused delegation of authority with both the State Game and Fish Commission and the City and County of Denver. The former is responsible not only for pollution damaging to aquatic life (as though the pollution which kills fish were distinct from that which affects the health of men) but for all pollution by mine tailings. Denver, City and County, is responsible for pollution control throughout the city's public water supply catchment area.

In other respects, Colorado's pollution legislation is somewhat stronger than Nebraska's. The Colorado Health Department's orders, rules, and regulations are backed by penalty provisions which include imprisonment as well as fines and the payment of expenses incurred by health authorities in removing "any nuisance, source of filth or cause of sickness."

In general, our Basin investigators found Colorado's pollution control program to be inadequate despite a good deal of effective work in this field by the Health Department. "Many cities and industries still discharge untreated or inadequately treated wastes into the waters of the State," said the Basin report. "Surface water resources are limited and a further complication results from extensive irrigation water use. A number of critical stream pollution problems exist." The investigators recommended, as they did for Nebraska, that comprehensive pollution control legislation be enacted, and the responsibility for enforcing it be placed in the Health Department. More staff and more funds are needed for this work.

There is one respect, however, in which Nebraska's statutes dealing with pollution control are definitely superior to Kansas's.

In Nebraska, all villages and cities may issue what are called "mortgage bonds" which do not impose any general liability upon the municipality but are specifically secured by the property for which the money was borrowed. Thus bonds issued to build a sewage plant and a sewer system could be secured by the plant and the sewers, and paid off by the revenues from these. This definitely implies that those people and industries who are serviced by the sewer system and plant may be charged for that service, a provision which is of great help to the financing of sewage treatment works by municipalities. It makes possible the fair distribution of operating cost payments among those who benefit from them: those who receive more, pay more in service charges; those who receive less, pay less--the same principle which is employed in the financing of public water supplies, or municipally owned electricity. The arrangement seems obviously equitable, and easily made.

In Kansas, however, it is not permitted by law in first and second class cities. Since 1929, third class cities have been allowed to make sewer service charges if they wished, and Ellsworth, Kansas, promptly took advantage of this permission when she purchased a private sewer system. Other third class towns followed suit. Cities of larger population, however, are denied this authority and this means that some of them can't raise more than one-fourth of the operating costs of their existing sewage treatment plants. When plant enlargements are needed the situation is even worse. The consequence is, on occasion, a serious and (under existing legislation) virtually insoluble pollution problem.

Take the case of Fort Scott, Kansas. It lies outside the Kansas Basin, but its experience is illustrative of the general problem. At the present time, Fort Scott is discharging untreated sewage into the Marmaton River, and since the early 1930's the Board of Health has received a steady stream of petitions and complaints from property owners downstream. In October, 1945, the Board ordered Fort Scott to treat its sewage and cease the pollution of the stream. A year later, the order having been ignored, action was initiated in the District Court to compel compliance. The city then prepared plans for a plant which would give primary treatment of the sewage, but it also proved that it could, under the present tax laws, raise only 40 percent of the proposed plant's operating costs. The court case has been pending ever since in the hope that some equitable arrangement can be worked out.

A few years ago the Board of Health selected at random 22 first and second class Kansas cities, and studied their financing of sewage treatment. It was found that 20 of the 22 could not, under existing legislation, obtain enough revenue to operate their plants. Only 20 percent of the needed money could be raised in some cities.

Obviously the only answer is passage of the needed permissive legislation. Why, then, has this not been done?

Certainly it has not been for lack of trying. Again and again the needed bill has been introduced in the Kansas legislature, buttressed by expert testimony and supported by sportsmen's organizations and other popular groups. Again and again the bill has died in committee or been killed on the floor. The manner of its death signifies once more that the problem of the river is, in the last analysis, a problem of men, and that a quality of moral corruption in the body politic may sometimes be gaged by the quantity of physical pollution in a stream.

"Corruption" is certainly too strong a description of the present case. But the fact remains that this repeated rejection of needed legislation has not proceeded from the popular will. Rather it has proceeded largely from the special interests of packing plants, and particularly from the Morrell Packing Company in Topeka. To see how great this special interest is, and how inequitable is the present system of financing sewage disposal, we can compare Morrell with the Santa Fe railroad company. Under present laws, sewage disposal is paid for out of property taxes--and on this basis Santa Fe, which maintains large offices and shops in Topeka, pays some $4,000 annually toward collection and treatment of the city's sewage. Morrell, on the other hand, pays only $400 in such taxes. Yet Santa Fe contributes very little sewage beyond that of the population it employs, whereas Morrell discharges wastes costing the city some $40,000 a year to handle and treat. In other words, Morrell pays just one percent of the cost of handling the wastes it discharges, and its privately profitable business is in effect subsidized by other tax payers to the tune of over $3,000 a month.

If these facts had been widely publicized, and if Morrell had appeared openly in the fight against sewer charge legislation, the latter would undoubtedly have been on Kansas books long ago. (Similar laws are now in effect in 28 states, and work well.) But those who stand to gain from inequitable arrangements generally prefer subterfuge and indirection to a frank and open battle, and they are aided in this by a press which feels small responsibility for actively uncovering and developing the news. The packers have never openly shown their hand; they have enlisted the support of the Kansas Chamber of Commerce, most of whose members have little or no conception of the issue; and the general impression has been created that the proposed legislation is mandatory rather than permissive in character and that it is "just another bill to increase taxes." Thus defeat has been assured.

What happened in 1949 is typical. The State Board of Health, having been urged to do so by several cities, joined in the drafting of the needed bill. In the drafting conferences, as a matter of fact, 24 municipalities and one township participated. The bill was presented to the House Committee on Hygiene and Public Health which held two hearings upon it and heard testimony unanimously favorable to it. The measure was then passed out as a committee bill and given House Number 224. But at this point, word came down from the Executive Mansion. The Governor was persuaded that the bill violated his campaign promise of "no tax increases" (though in fact it did not), and he therefore hoped it would not come to a floor vote. Why not, as quietly as possible, bury it alive?

A convenient if rather dishonest device exists for just that purpose in the Kansas legislature, as it does in most legislative bodies. There is a State Affairs Committee whose members are well aware that any bill referred to them is to be acted upon unfavorably: they refer to themselves jocularly as the "graveyard committee." And when--abruptly and with no public explanation--House Bill No. 224 was sent to them they did their jobs well. Despite the fact that the Committee competent to pass on such legislation had held full hearings and, on the basis of them, approved the measure, the State Affairs Committee held a hearing of its own. Just one hearing. Though it was by no means widely publicized in advance, at least 25 people came to argue for the bill while only two came to oppose it. The bill was then disapproved.....

3.

Silt Pollution: A Wider Reference....

We have left to the last a brief consideration of the problem of silt pollution and its abatement. We have done so, not because it is of minor importance--indeed turbidity produced by erosion silt is, as we've seen, integral to the problem of organic pollution--but because a consideration of it leads us inevitably to that wider reference with which we began this booklet and with which we seek to close it.

In addition to the turbidity it produces in the body of a stream, erosion silt affects water use and river development in two important ways. It complicates the processes by which water is purified for drinking purposes, and it increases the costs and lowers the long-time effectiveness of dams and reservoirs.

A decade ago the Soil Conservation Service made a study of water treatment in 22 cities of the Piedmont area in North Carolina. It was found that the average treatment cost there, including overhead and amortization of plant and equipment, was $70 per million gallons (it must certainly be much higher today), of which $27 was for treatment processes and $5 for chemicals--the chief of the latter being alum, used for the settlement of suspended solids.

The Service estimated that an adequate soil conservation program in that region would reduce the suspended load of streams by 30 percent, at least--and this would result in an average immediate saving of $1.50 per million gallons. "Considering the future savings from smaller capital outlay for new settling basins and plant equipment, reduced flushing costs and other plant operations, the total savings eventually would be $7 per million gallons or $94,000 annually for the 22 cities. If we could save only $1 per million gallons on all of the surface water of the United States which had to be filtered for domestic or industrial use, we would bring about an annual benefit of $1,400,000. We should be able to save at least seven times this much, or around $10,000,000 annually, to municipalities and industries through soil conservation work on the watershed above the reservoirs."[1]

More serious by far is the reduction of reservoir capacity by sedimentation. It has been estimated[2] that the annual cost of reservoir silting is upwards of $50,000,000 and that many reservoirs important to our war effort in 1944 were losing 1, 2, 3, and even 5 percent of their capacity every year through silting.

Because of soil erosion, an important factor to be considered in the design of reservoirs is the so-called "capacity-watershed ratio." If two reservoirs of the same size are located in areas having the same erosion rate, the reservoir which drains the larger area will, of course, silt up more rapidly than that which drains the smaller one. The capacity-watershed (C / W) ratio is a figure indicating the relationship of reservoir capacity to watershed area, the former being stated in acre-feet and the latter in square miles. Thus if a reservoir has a capacity of 50,000 acre-feet, and drains a watershed of 2,000 square miles, the capacity-watershed ratio (C / W) is 50,000 divided by 2,000, or 25 acre-feet per square mile--a dangerously low ratio, incidentally, in most areas.

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[1] "Stream Pollution by Erosion Silt," H. H. Bennett, Chief, Soil Conservation Service. Reprinted from hearings before the Committee on Rivers and Harbors on water pollution control bills Nos. 13, 14, 15, and 20, 1945.

[2] By H. H. Bennett in Foreword to "The Control of Reservoir Silting," by Carl B. Brown, U. S. Department of Agriculture, Miscellaneous Publication No. 521.

Some very costly errors in design have stemmed from a failure to give this C/W ratio its proper weight. One of them occurred only a few years ago at Osborne, Kansas, on the Solomon River. Here a water supply reservoir was built in 1936 at a cost of approximately $150,000--a very substantial cost for a municipality of some 1,900 population. The reservoir capacity was small, only about 300 acre-feet, though sufficient to supply Osborne's needs. The drainage area above the reservoir, however, was large, approximately 2,100 square miles, which meant a C/W ratio of a mere 0.14 acre-foot per square mile. Within one year after completion, that reservoir was completely filled with silt! At least a dozen similar failures of reservoirs constructed since 1930 are on record.

But it must be emphasized that the importance of the C/W ratio depends upon the rate of erosion, and its value as a determinant of reservoir design can be greatly varied by the establishment of soil conservation practices. Indeed, the purely technical possibilities of watershed erosion control are very great. Merely by assigning each acre to the uses for which it is best fitted--protecting highly erodible slopes with permanent vegetative cover and practicing good rotations on all cultivated land--soil losses can be cut to a fraction of their former amount on most watersheds, and surface water runoff (so important to flood control planning) can be significantly reduced. Consider, for example, research data obtained at Bethany, Missouri, on Shelby Silt Loam, a soil type similar to those covering large parts of the Kansas River Basin. The land on which the experiments were made had a slope of 8 percent, which is to say that it had an 8-foot vertical drop for every 100 feet on the horizontal. When planted continuously to corn, it lost nearly 19 tons of soil per acre each year over a 10-year period. When planted to a recommended rotation of corn, barley, and clover-timothy, it lost only a little more than 4 tons per acre annually, a reduction of almost 80 percent in soil-loss rates. Water losses, too, were reduced, though not so drastically. Land cropped continuously in corn lost, as surface runoff, a little more than 27 percent of all the rain falling upon it, whereas the land in 3-year rotation lost only a little more than 16 percent.

When to these general use assignments are added other soil-saving devices--such as contour tillage, strip cropping, terracing, and gully control dams--runoff and soil loss rates are still further cut. Straight-row up and down cultivation was compared with contour cultivation (in which the rows run level around the slopes) on land with a slope of between 6 and 7 percent at the Bethany experiment station. All other factors influencing erosion and runoff rates were held constant. It was found that land cultivated in a straight row lost nearly 164 tons of soil per acre while land cultivated on the contour lost only 21.31 tons per acre over a seven-year period. Sixteen percent of the water falling on the straight-rowed field was lost as runoff, while 14 percent of the water falling on the contoured field was so lost. Strip-cropping, in which alternating strips of row and cover crops are planted on the contour, thus breaking a long slope up into a series of shorter ones, markedly increases the effectiveness of contour cultivation. If terracing is combined with strip-cropping, a still greater reduction of soil and water losses may be effected.

Small wonder that many cities now are actively concerning themselves with the promotion of soil conserving practices in the watersheds feeding their reservoirs. The experience of Decatur, Illinois, is representative. This city draws its water from the artificial Lake Decatur, backed up by a dam which (with the needed land) cost $2,013,000. In 1936 a survey revealed that in 14 years the reservoir had lost more than 14 percent of its original capacity of nearly 20,000 acre-feet. The city fathers were justifiably alarmed, and their alarm was compounded when industrial uses of water began making plans to move elsewhere: one of the city's largest soy bean processing plants, for example, took an option on an alternative factory site on Lake Erie. So in 1941, the city began appropriating $12,000 a year to promote erosion control in the lake's 906-square-mile watershed; two full-time soil conservation specialists were hired; and a 10-year program designed to provide complete conservation practices on a majority of the watershed farms was inaugurated.

Our main point, however, is that this kind of water pollution problem requires for its solution a much wider frame of reference than does the problem of sewage disposal--assuming for the moment that the latter can be treated in isolation. Abatement of pollution by municipalities and private industries requires, as we have seen, social action--but it is action confined for the most part to the stream itself, and its banks. Not so the abatement of erosion silt pollution. This problem can be solved only in terms of the watershed as a whole, and it requires the cooperation not only of highly organized groups--like city governments and industries--but of farmers who, for all the Federal farm programs (indeed, largely because of them), yet remain unorganized, largely self-determining entrepreneurs. Town and country must work together.

In this connection, the stated objectives of the conservation association formed in Decatur, Illinois, are significant. One of them is "to foster rural-urban cooperation in an attack on soil wastage." The statement continues:

"Since the loss in soil results in lower soil productivity and purchasing power, lowered land values, reservoir and stream silting, and decreased standards of living, all of which affect both farm and city people, it is important that the attack be united."